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INTERNATIONAL SECURITY AND SCIENCE

OF THE

COMMITTEE ON FOREIGN AFFAIRS
U.S. HOUSE OF REPRESENTATIVES

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FOREWORD

As chairman of the Committee on Foreign Affairs and its Subcommittee on Arms Control, International Security and Science, I requested the Congressional Research Service (CRS) in August 1984 to conduct a comprehensive study of U.S. nuclear arms control policy.

In accordance with my interest in augmenting congressional participation in nuclear arms control policy issues, the committee and CRS sponsored a series of arms control workshops for Members of Congress. The sessions were based on a comprehensive CRS study entitled "Fundamentals of Nuclear Arms Control."

This chapter of the study is entitled "Technological Change and Nuclear Arms Control." It is the seventh in a series of committee prints on the CRS study.

Utilizing this chapter on technological change and arms control, the Committee on Foreign Affairs conducted an arms control workshop on September 12, 1985. At the workshop, distinguished guest experts Richard D. DeLauer and Jack P. Ruina discussed the implications of technological changes for nuclear arms control and the prospects for constraining and influencing the rate and direction of technological change through arms control. Richard DeLauer, who is currently president of the Orion Group, a Virginia-based technical consulting firm, has previously served as Under Secretary of Defense for Research and Engineering. Jack Ruina, a professor of electrical engineering at Massachusetts Institute of Technology, has held numerous government posts, including assistant director of Defense Research and Engineering and deputy for research to the Assistant Secretary for Research and Engineering, U.S. Air Force. Stanley Heginbotham of CRS moderated the discussion.

The committee's periodic arms control workshops, which are based on the CRS studies, are designed to allow Members of Congress a forum in which to explore the impact of nuclear arms control on our country's national security. It is my belief that Congress must be prepared to offer constructive nuclear arms control solutions that are based on an understanding of a number of complex issues. This comprehensive study attempts to make a contribution to that effort.

The views expressed in this committee print are those of the Congressional Research Service and do not necessarily reflect the views of the members of the Committee on Foreign Affairs.

DANTE B. FASCELL, *Chairman.*

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LETTER OF SUBMITTAL

CONGRESSIONAL RESEARCH SERVICE,
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Washington, DC, May 2, 1986.

Hon. DANTE B. FASCELL,
Chairman, Committee on Foreign Affairs, U.S. House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: I am pleased to submit the study, "Technological Change and Nuclear Arms Control," part of the series entitled "The Fundamentals of Nuclear Arms Control," as requested by the committee.

This study examines the implications of currently foreseen technological changes for nuclear arms control and the prospects for influencing the rate and direction of technological change through arms control. The historical record is examined, as well as the effects of technological asymmetries on arms control. Four areas of significant technological change being introduced are discussed: Long-range cruise missiles, ballistic missile defense, antisatellite weaponry, and some aspects of ICBM technology.

The report was prepared by Dr. Ted Greenwood, Consultant to the Foreign Affairs and National Defense Division. The series is being coordinated by Leneice N. Wu, Specialist in International Relations, under the direction of Stanley J. Heginbotham, Chief.

Sincerely,

JOSEPH E. ROSS,
Director.

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EXECUTIVE SUMMARY

The current arms control negotiations between the United States and the Soviet Union are occurring at a time of rapid technological change in both offensive and defensive nuclear weaponry. The course of these negotiations and the nature of any resulting agreement will be strongly influenced by the pace, direction, and anticipated utility of current technological innovation, just as negotiations and agreements in the past have been. Similarly, a future arms control agreement might influence the rate and direction of technological change, again, just as past agreements occasionally have. The objective of this paper is to explore the extent and nature of the two-way interaction between technological change and nuclear arms control. It tries to shed light on two questions: (1) What are the implications of currently foreseen technological changes for nuclear arms control; and (2) Are the prospects for constraining or, more generally, influencing the rate and direction of technological change through arms control greater now than they have been in the past?

Influencing Technological Change Through Arms Control

Arms control, meaning here the pursuit of agreement and particular agreements that are achieved, can in principle influence technological change in the field of nuclear weaponry either by constraining or by promoting such change. Doing either, however, turns out to be quite difficult in practice and has rarely occurred.

Agreements have prohibited activities with the intention of constraining activities, but the resulting constraints have almost always been minimal or unimportant. Similarly, the desire to promote arms control has only rarely influenced the rate and direction of technological change. The explanation for these historical facts is twofold:

—Arms control considerations must compete with strategic, economic, organizational, and political considerations for influence in the U.S. and Soviet decisionmaking processes that allocate resources for R&D and weapons procurement and determine arms control strategy. In this competition, arms control considerations tend usually to be subordinated to others with more powerful constituencies and rarely exert much influence over the rate and direction of technological change. Constraints on technological change are very difficult to achieve by arms control agreement when such changes are perceived to have strategic, economic, organizational, or political significance.

—The need for both parties to an important arms control agreement to be able with quite high confidence to verify compliance by the other discourages agreements that constrain tech-

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nological change because incipient change is frequently difficult to detect until it has evolved so far that compliance with an agreement to constrain it can no longer be verified with high confidence.

The Historical Record

The list of areas of potential technological change that have been constrained or cut off by arms control agreements is quite lengthy. However, in no case has an agreement inhibited technological change that the United States actually wanted to pursue at the time of agreement and was capable of pursuing during the intended duration of the agreement. Only in one area (SALT II constraints on the number of MIRV's on existing missiles) is it possible that such agreements actually inhibited Soviet programs, although in another (testing of new light ICBM's), their program is claimed by the United States to violate the SALT II Treaty that the Soviets have stated they will not undercut. Agreements have been reached, in other words, with few exceptions only when they prohibited things neither side wanted to do, when prohibited activities could not be carried out within the intended duration of the agreement anyway, or when they were ambiguous enough to permit an interpretation that did not restrict intended innovation.

Where agreements to constrain technology would have been truly meaningful, efforts to achieve them have either failed (as with nuclear weapons testing, hard target kill capability, mobile ICBM's, and cruise missiles) or not been made (as with MIRV'ing, accuracy improvement, silo hardness, and antisubmarine warfare). In the area of ballistic missile defense, a conscious effort was made in the ABM Treaty to constrain technological change that might emerge and be important in the future. Now that such technology is of interest, however, the treaty may not be able to withstand pressures to reinterpret it in a way that eliminates the now unwanted constraints.

Arms control negotiations and agreements have encouraged technological change indirectly in several areas, notably cold-launch techniques for ICBM's, antiballistic missile deployment, and cruise missiles.

The Effects of Technological Asymmetries on Arms Control

Most of the ways in which the fact or prospect of technological change influences arms control can best be understood by focusing on the phenomenon of asymmetry with respect to the state of technology in the United States and the Soviet Union. Such asymmetry sometimes promotes and sometimes inhibits arms control agreements, and under various conditions being both ahead and behind can provide incentives in either direction.

Technological leads promote arms control in the role of bargaining chips only if the possessor of the lead believes the area of technology is sufficiently unpromising or of such little strategic value that it can be forgone with little loss, but the opponent believes or fears the opposite. If the follower believes that the technology is of little strategic value, that country will not be induced to trade anything significant to impose constraints on the leader. If the leader

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believes the lead can be usefully exploited, he will be very reluctant to give it up, but he may be more willing to accept an agreement that is painful in other respects if exploitation of the technological lead is not inhibited.

Technological lags can provide incentives to reach agreement if the follower believes the technology is important and either that he will not catch up technologically or that equal exploitation will favor the other side. Technological lags will provide disincentives, however, if the follower believes both that he can catch up and that unconstrained exploitation will eventually favor himself.

Technological Change and the Future of Arms Control

From the perspective of 1986, one can identify four areas of nuclear weaponry where significant technological change is being introduced or is on the horizon that either will influence arms control negotiations now underway or are candidates for encouragement or limitation through arms control. These are long-range cruise missiles, ballistic missile defense, antisatellite weaponry, and some aspects of ICBM technology.

Long-range sea- and ground-launched cruise missiles seem very difficult to constrain meaningfully through arms control agreements because of difficulties of verification. As a result, they are likely to complicate and might render impossible agreement to control other categories of offensive nuclear weapons.

The continuing evolution of ballistic missile defense technology cannot be arrested totally by agreement, even if that were judged desirable, and the mutual fear of breakout from the ABM Treaty cannot be totally eliminated. The potential value of space-based ballistic missile defense technology and its likely implications for offensive arms control are hotly debated issues. What seems clear is that, in the near term, the only attainable agreement that goes beyond the ABM Treaty would be to expand the definition of development and testing in order to prohibit all out-of-laboratory testing.

Disagreements also exist over whether antisatellite technology should be left unconstrained or limited by agreement. Proponents of the technology argue that U.S. national security would be served by having the capability to attack certain Soviet satellites, especially those for ocean surveillance, photoreconnaissance and electronic surveillance. Opponents argue that the United States should be willing to forgo this capability if it could thereby constrain Soviet antisatellite capability and ensure the survivability of U.S. satellites. Aside from desirability, however, the feasibility of agreement is highly uncertain for three reasons: (1) The political pressures generated by current asymmetries in deployed capability and technology; (2) the technical difficulties of verification; and (3) the inherent difficulty of effectively constraining antisatellite technology while permitting the continuation of activities and the evolution of technologies with other purposes but possessing some intrinsic antisatellite capability.

Two areas of new ICBM technology are particularly important and might influence or be influenced by arms control. These are high-accuracy maneuvering reentry vehicles and mobile ICBM's.

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One version of a maneuvering reentry vehicle has already been deployed on the long-range theater ballistic missile, the Pershing II, and others are likely to be placed on ICBM's (and SLBM's) in the future, unless prohibited by agreement. This technology might be constrained by agreeing to a mutual test ban, although it might already be too far advanced for this to be feasible. Mobile ICBM's are being deployed by the Soviet Union and may be deployed by the United States unless prohibited by agreement. If deployment does go forward, reaching agreement on offensive nuclear weaponry will be rendered much more difficult and perhaps even be precluded unless the systems are designed so that the inability of an opponent to target the missiles does not prevent verification of the number deployed.

The small, single warhead, mobile ICBM currently under study in the United States might be vulnerable to barrage attacks. It is not necessarily the best trade-off between cost-effectiveness and the desire to avoid an offense-defense exchange ratio favorable to the offense, and will not be deployed without considerable opposition. The system would appear to be unattractive both economically and strategically unless it were deployed in the context of an arms control agreement that forced a sharp reduction in Soviet warheads.

There is no reason, *a priori*, to expect greater success in the future, than in the past at employing nuclear arms control to constrain technological change. The examination of four areas of evolving technology yields nothing to alter this expectation. Verification difficulties alone are a serious impediment. But beyond that, no consensus exists that constraining technological evolution is preferable to unconstrained exploitation. The result is little prospect of agreement in the current negotiations that constrains technological change. In several areas, however—particularly sea- and land-based cruise missiles and mobile ICBM's—the prospect of such change will importantly complicate the negotiations and may preclude agreement in other areas. In the area of ballistic missile defense, the prospect of technological change might unravel an agreement now in effect.

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I. INTRODUCTION

The current arms control discussions between the United States and Soviet Union are occurring at a time of rapid technological change in nuclear weaponry. New long-range bombers, new ballistic missiles and submarines, new intercontinental and submarine-launched ballistic missiles with improved accuracy and, in some cases, larger numbers of independently targetable warheads, new long-range cruise missiles, and improved command and control systems are being developed or deployed by both sides. These promise significant and in some instances dramatic improvements in offensive capability. The pursuit in both countries of technologies for boost-phase interception of ballistic missiles is believed by some to promise a major revolution in defensive capability that will reverse the dominance of nuclear offense over defense. Development in the United States of antisatellite weapons which are expected to be more capable than the existing Soviet system and the probability that the Soviet capability will improve presage the erosion of near-earth space as a sanctuary for intelligence collection and communications assets.

Such technological change in nuclear weaponry is not unique to the current period; it has characterized the entire postwar era, although its pace has fluctuated over time. Nevertheless, the course of the current negotiations and the nature of any resulting agreement will be strongly influenced by the pace, direction, and anticipated utility of current technological innovation, just as negotiations and agreement in the past have been. Similarly, a future arms control agreement might influence the rate and direction of technological change, again, just as past agreements occasionally have. It is the objective of this paper to explore the extent and nature of the two-way interaction between technological change and nuclear arms control.

Technological Forecasting

As seen from the perspective of any moment, specific technological changes may be either underway or expected in the future. The characteristics and military implications of changes that are underway or will occur soon are usually well understood. This is the case, for example, for the B–1 bomber currently. For change anticipated in the more distant future, technological forecasting is necessary. Although difficult and uncertain, such forecasting cannot be avoided in the development of an arms control strategy and when conducting negotiations. In order to decide what sort of arms control agreement would be desirable or acceptable, to close possible loopholes that might give future advantage to an opponent, and to have some confidence that an agreement will endure, forecasts must be made about the rate, direction and implications of future

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technological change both for one's own capabilities and for one's opponent's.

Such forecasts are based on information of several kinds: Projections of technological possibilities that flow out of national research and development (R&D) programs; intelligence about an opponent's R&D programs that derives from studying scientific and military writings, from technical collection systems, and perhaps from human sources; and a general understanding of the nature and competence of an opponent's R&D capabilities.

Uncertainties always exist in technological forecasts; however, the more so, the further into the future they reach. What will turn out to be feasible and economically attractive is at least as difficult to predict in the arena of nuclear weaponry as in any other. Moreover, one is faced here not only with the constraints of nature and the limitations of one's resources and inventiveness, but also with a persistent, capable and resourceful adversary who can also develop new technologies and employ existing technologies in significant new ways.

For one's own innovations less than 10 years distant, such as the Trident II (D–5) missile, the general features are likely to be reasonably fixed and only the precise value of performance characteristics, such as accuracy and reliability, are uncertain. For one's own innovations over a longer time, however, such as Midgetman or stealth technology currently, even general characteristics, such as basing mode, might be uncertain.

For innovations of an opponent, the general characteristics of even near-term developments, such as the SS–X–24 or SS–18 replacements today, are often highly uncertain. Intelligence about the opponent's activities will be incomplete and may be unreliable or contradictory, especially during the early stages of development of a new technology or a new system. Moreover, accurate interpretation of intelligence data is notoriously difficult. For possibly radical but quite distant technology, such as space-based directed-energy weapons being considered for boost-phase interception of ballistic missiles, all forecasts of even the general architecture or strategic implications of a system, should the technology ever prove cost-effective, must be highly speculative.

Technological Change Affects Arms Control

The fact that technological change constantly occurs in the field of nuclear weapons systems has had and will continue to have important implications for the negotiation, achievement, content, and endurance of arms control agreements. Moreover, such implications have been, and will continue to be, complex, specific to each area of technology and difficult to predict. Sometimes the prospect of new technology suggests the need for an agreement to constrain its evolution. That is the view of many people today with respect to antisatellite and space-based ballistic missile defense technology. Sometimes the prospect of new technology facilitates achievement of an agreement in other areas. The anticipation of U.S. MIRV capability, for example, made the United States more willing to reach agreement with the Soviet Union on offensive weapons in 1972 and made the agreement more acceptable to the Congress and

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the country. Certainly no significant arms control would be possible without the dramatic innovation in national technical means of verification: Photoreconnaissance and electronic intelligence satellites, the ability to observe missile tests with land- and ship-based radars, and sensitive radio receivers that can pick up telemetry data from missile tests.

Sometimes, however, the prospect of technological change makes agreement more difficult. This was the case during SALT I, when the United States perceived that the Soviets might upgrade their so-called Tallin air defense system to give it some ABM capabilities. Similarly, during the negotiation of SALT II, this was the Soviet view of the prospect of U.S. cruise missile deployments. The implications for arms control of future innovation might also be highly uncertain. Proponents of the Reagan administration's Strategic Defense Initative, for example, argue that a capable ballistic missile defense of population would facilitate agreement with the Soviet Union on the limitation of offensive nuclear weapons, while opponents argue that efforts to achieve such a defense will eliminate any prospect of such agreement.

Agreements sometimes have taken explicit account of the possibility of technical change. The ABM Treaty did so, for example, by banning sea-based, air-based, space-based and mobile land-based missile defense systems. Sometimes the implications of future technology are not adequately taken into account in an agreement, whether because the change is not anticipated, its significance not understood, or agreement cannot be reached. When this occurs, technological change can ultimately undermine the agreement. For example, despite U.S. efforts to do so, the SALT I interim agreement did not deal with the Soviet replacement of SS-11 ICBM's by significantly larger and more capable missiles in the same launchers. This Soviet action was widely regarded in the United States as a circumvention of the limitations on heavy missiles and a violation of the spirit of the agreement. It soured many people's view of the arms control enterprise.

Certainly, in light of the 20-year experience with nuclear arms control agreements, the prospects for and implications of technological change seem likely to be considered with great care during any future negotiation and when deciding whether a particular proposed agreement is desirable.

Arms Control Influences Technological Change

Arms control negotiations have sometimes tried to constrain or, more generally, influence the direction of technological change. As we shall see, however, such objectives are difficult to achieve for significant changes and success has been minimal to date. One objective of advocates of a comprehensive nuclear test ban for 25 years, for example, has been to slow down or stop altogether the evolution of nuclear explosives technology and thereby constrain or prevent the deployment of new nuclear systems for which existing weapon designs would be adequate. Although the 1963 limited test-ban treaty was opposed in part by those who feared such effects, in fact the continuation of underground testing has permitted explo-

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sives technology to evolve without significant constraints.[1] Similarly, U.S. efforts to constrain Soviet hard-target-kill capability through negotiation has had little, if any, effect despite the SALT I and II constraints on heavy Soviet ICBM's and SALT II contraints on the number of warheads ICBM's and SLBM's may carry. The same is true for Soviet efforts during the negotiations on SALT II to constrain U.S. cruise missile deployments. A notable exception to this general pattern is the ABM Treaty. At the time it was signed, this treaty was believed to constrain technological development in ways that, although not immediately significant, might become so in the future.

Objectives of This Report

This paper tries to shed light on two questions: (1) What the implications of currently foreseen technological changes are for nuclear arms control; and (2) whether the prospects for constraining or, more generally, influencing the rate and direction of technological change through arms control are greater now than they have been in the past. In doing so, it will draw heavily on the lessons of historical experience.

Conclusions

The paper first identifies two reasons why influencing technological change through arms control is difficult. The first is that strategic, economic, organizational and political considerations often overwhelm arms control considerations in national decisionmaking about R&D choices, weapons deployment, and arms control strategy. The result is that negotiated constraints on significant technological change are difficult to achieve. The second reason is that the requirement that each party to an agreement be able to verify compliance by the other prevents or at least discourages consideration of many potential agreements that might influence technological change.

The historical record of efforts to exert influence on technological change through arms control is then examined. The major conclusion is that, with very few exceptions, agreements have been reached only when they prohibited something that would have had little if any military significance and that neither side wanted to do; when the prohibited activities, although significant, could not be carried out within the duration of the agreement; or when the agreements were ambiguous enough to permit an interpretation that did not prevent intented introductions of new technology. When agreements to constrain technological change would have been meaningful, they almost always were either not sought or sought by one side without success. In the case of the ABM Treaty, which is an exception, a conscious effort was made to constrain technology that might emerge and be important in the future. Now that such technology is of interest, however, the treaty may not be able to withstand the pressures to proceed with its development.

[1] The limited test ban treaty is sometimes said to have inhibited the acquisition of nuclear weapons by some non-nuclear-weapons states. However, this is a controversial claim.

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Ambiguities in the treaty's provisions have permitted reinterpretation that has eliminated the now unwanted constraints.

The effects of technological change on efforts to achieve arms control agreements are examined by focusing on the fact of technological asymmetry that continues to exist between the United States and the Soviet Union. Having a technological lead is found sometimes to promote agreement, either by providing bargaining leverage or by encouraging a willingness to accept constraints in other areas. But a technological lead can also inhibit agreement that would constrain a technology's exploitation if the leader thinks it would benefit from such exploitation. Lagging in technology can engender a desire to achieve an agreement that would constrain the leader, if the follower believes either that it will not be able to catch up or that equal exploitation will favor the other side. Technology lags will provide disincentives to agree, if the follower believes both that it can catch up and that unconstrained exploitation will eventually favor itself.

Finally, four specific areas of currently foreseen technological change—long-range nuclear cruise missiles, new ballistic missile defense technology, antisatellite systems, and changes in ICBM technology—will be examined to see what effects they are likely to have on prospects for arms control and the extent to which constraint, if judged desirable, could be achieved by agreement. Deployments of cruise missiles, perhaps of mobile ICBM's, and, according to some, of space-based ballistic missile defense would greatly complicate and might preclude further agreement to limit offensive nuclear weaponry. Proponents of the latter technology, however, claim that it will have the opposite effect. Agreements to constrain the deployment of cruise missiles, antisatellite systems or maneuvering reentry vehicles for ICBM's or to further constrain ballistic missile defense technology are likely to be very difficult to achieve. The reasons include problems of verification, the presence of technological asymmetries, and the disagreement between the United States and the Soviet Union whether limitation or unconstrained evolution of the technologies would be preferable.

A Caveat

Before proceeding, it should be noted that there is no consensus in the United States among either citizens or decisionmakers about objectives for nuclear forces or nuclear arms control policy, about the relative weight that should be assigned to various competing objectives, or about the extent to which, or even whether, various R&D programs and weapons systems contribute to or detract from the pursuit of various objectives. Therefore, the arms control and strategic implications of technological changes and how best to channel innovative activity so that it will serve arms control interest or particular strategic objectives are frequently uncertain and matters of contentious debate. Arguments derived from arms control and strategic consideration can be and are made by those who support or oppose weapon systems or avenues of technological change for other reasons. That is currently the case, for example, with President Reagan's Strategic Defense Initiative and has been the case for the MX missile for many years.

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This ambiguity about objectives and the implications of proposed actions not only ensures continual debate over all nuclear weapons and arms control issues in the United States, but also renders definitive analysis of the interrelationship of technological change and arms control problematic. In what follows, therefore, a range of views on most of the issues is presented.

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II. INFLUENCING TECHNOLOGICAL CHANGE THROUGH ARMS CONTROL

Arms control, meaning here both the pursuit of agreement and particular agreements that are achieved, can in principle influence technological change in the field of nuclear weaponry in two ways. First, it can constrain technological change, either directly through agreements that foreclose or limit particular avenues of innovation, or indirectly by discouraging countries from focusing innovative activity in particular directions. Second, arms control can promote technological change by leaving some avenues unconstrained while inhibiting others, by encouraging innovations along particular routes, and potentially by agreeing to institute changes or reopening avenues previously closed in earlier arms control agreements.[1] Doing either, however, turns out to be quite difficult in practice and has rarely occurred.

The most definitive way for arms control to influence the rate and direction of technological change is for an agreement to specify that something is required or prohibited. The former has not occurred.[2] The reasons why new weapons technology has not been required by arms control agreements are not altogether clear, but probably include at least three factors: The simplistic but widely held view that new nuclear technology is destabilizing or otherwise bad and therefore that arms control should constrain, not promote, new weapons deployments; a belief that new technology, such as harder silos or improved command and control, that may be mutually beneficial will be introduced to the extent feasible, without being encouraged by arms control agreements; and a perception that innovations would not benefit both sides equally, resulting in at least one side's not wishing to encourage any potential technological change through an arms control agreement.

Agreements have prohibited activities with the intention of constraining technological change but, as we shall see in the next section, the resulting constraints have almost always been minimal or unimportant. The reason is twofold. First, the difficulties of verification have discouraged the pursuit of agreements that explicitly constrain technological change. Second, where verification has not been a determining factor, the proponents of technological change

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[1] Omitted from consideration here is the influence that arms control agreements and the efforts to achieve them have had on the evolution of verification technology. This has been especially strong in the areas of seismology, as applied to detection and discrimination of underground nuclear testing, and safeguards applied to civilian nuclear facilities to ensure that nuclear materials are not transferred to military uses. Verification is addressed in another paper in this series: U.S. Congress. House, Committee on Foreign Affairs. Subcommittee on Arms Control, International Security and Science. Fundamentals of Nuclear Arms Control. Part IV, Treaty Compliance and Nuclear Arms Control. Committee Print, June 19, 1985. Washington, U.S. Government Printing Office, 23 pp.

[2] Agreements have been reached in the area of confidence-building measures that have required the employment of communications capability to establish and subsequently to upgrade the Washington-to-Moscow hotline. Memorandum of Understanding Between the United States of America and the Union of Soviet Socialist Republics Regarding the Establishment of a Direct Communication Link and Its Annex (entered into force June 20, 1963); Agreement Between the United States of America and the Union of Soviet Socialist Republics on Measures To Improve the U.S.-U.S.S.R. Direct Communication Link and Its Annex (entered into force Sept. 30, 1971); U.S. Department of State July 17, 1984, note to the Soviet Embassy concerning adding facsimile communication to the Direct Communication Link and the reply by the Soviet Embassy of July 17, 1984. However, these agreements called for exploitation of existing technology and did not influence the rate or direction of technological change.

in both the United States and the Soviet Union have almost always been politically strong enough to overcome proponents of constraint and to prevent either country from agreeing to significant constraint.

The desire to promote arms control can also influence technological change. The so-called build-down proposals of recent years are examples to the extent that they encourage the modernization of one area of mobile nuclear weaponry (for example SLBM's or ICBM's) more than another (for example fixed landbased ICBM's). To have a promotional effect, however, arms control considerations must compete with others for influence over R&D and weapons choices. Even when general agreement exists about what arms control considerations imply, such considerations have a difficult time achieving ascendency within the weapons acquisition community and the budget process that allocates resources. Opposing forces usually have better placed and more powerful proponents.

This section examines first the various considerations with which arms control must compete for influence and then verification issues, identifying why both render agreement to constrain technological change difficult.

A. Considerations That Compete With Arms Control

Four types of considerations—strategic, economic, organizational, and political—compete with each other and with arms control for influence in the U.S. and Soviet decisionmaking processes that allocate resources for R&D and weapons procurement and that determine arms control strategy. These considerations usually take priority over arms control and frequently promote technological change where arms control considerations might argue for restraint.

STRATEGIC CONSIDERATIONS

By strategic considerations is meant concern whether proposed actions will contribute to or detract from any of the many objectives that national governments have for nuclear forces. These objectives include contributing to bilateral deterrence, for the United States contributing to extended deterrence, contributing to the potential for armed suasion of other kinds, enhancing prestige and engendering respect by other states, reducing incentives for initiating war, and limiting damage if war should occur. The force structure implications of these various objectives are quite contradictory and virtually any R&D or procurement proposal can be supported or opposed by reference to one or more of them. But those objectives that have actually dominated government policy in both countries encourage steady improvement in capabilities. Therefore, strategic considerations alone have provided incentives for technological changes that promise such improvement.

ECONOMIC CONSIDERATIONS

By economic considerations is meant concern for cost and cost-effectiveness. Given any set of strategic objectives, the approach that achieves them at least cost is likely to command support by

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those who oversee budget expenditures. Similarly, given a constrained budget, the approach which maximizes effectiveness by some preferred criteria will also command support. Of course there exists a multiplicity of possible objectives, each weapons system contributes to them differently, and consensus can rarely be achieved on criteria. Therefore, cost and strategy must normally be considered together. Strategic defense of populations, for example, might be advocated, but not if it costs more than some figure judged the maximum reasonable. Accurate, MIRVed missiles might be objected to in principle because they threaten an opponent's targetable nuclear weapons, but might be preferred to single-warhead missiles if the latter's cost to achieve desired target coverage is much greater. Cost-effectiveness considerations often generate support for the pursuit of more effective technology and weapon systems and frequently argue for innovation to replace systems that are becoming unreliable, expensive to maintain, or ineffective in the face of an opponent's counteractions.

ORGANIZATIONAL CONSIDERATIONS

Organizational considerations derive from the desire of military services and defense contractors to promote their organizational interests. Although the military sometimes resists technological change when it anticipates disruption of established patterns of authority or influence within the organization, the interest of both Soviet and U.S. military services in maintaining or expanding missions and budgets has caused the dominant organizational incentive since World War II, especially in the nuclear area, to be toward innovation. Military personnel promote the organizational interests of their services within decisionmaking councils and skillfully employ strategic and economic arguments that serve as justifying ideologies for these interests.[3]

Defense industries or, in the Soviet Union, ministries and design bureaus [4] require either force structure expansion with existing systems or a turnover of hardware through technological change in order to remain viable organizations. Competition often provides incentives to develop and exploit new technology. In both countries, the complex interaction among the services, defense industries, and design bureaus keeps a steady flow of new ideas percolating up through the R&D and weapons acquisition communites. Only a small success rate is necessary to ensure continual development and deployment of new systems.

POLITICAL CONSIDERATIONS

Many types of political considerations are relevant to R&D and weapons choices. In the domestic context, leaders have to accommodate the preferences of powerful actors within their political

[3] See, for example, Greenwood, Ted. Making the MIRV: A Study of Defense Decision Making. Cambridge, Mass, Ballinger, 1975. Chapter 3; Sapolsky, Harvey M. The Polaris System Development: Bureaucratic and Programmatic Success in Government. Cambridge, Mass., Harvard University Press, 1972; and Armacost, Michael H. The Politics of Weapons Innovation: The Thor-Jupiter Controversy. New York, Columbia University Press, 1969.

[4] For a discussion of the role of Soviet ministries and design bureaus in strategic missile development, see Berman, Robert, and John C. Baker. Soviet Strategic Forces: Requirements and Responses. Washington, Brookings Institution, 1982. Appendix A.

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system. Such actors may include not only the military services and defense industries, but also organized sectors of the public and legislators reflecting their views about national security or the interests of their districts and constitutents. For example, President Johnson's decisions to deploy the Poseidon SLBM and a light ABM system were both influenced strongly by his perceived need to accommodate strong congressional proponents of and public pressure for more vigorous defense investment. In addition, each time an arms control agreement that would significantly constrain U.S. defense programs has been signed by the President, the armed services have exacted a price in terms of continued R&D or new weapons deployment for their badly needed endorsement. In the case of SALT I, for example, the President gave the Joint Chiefs of Staff three assurances: A broad range of intelligence capabilities and operations to verify Soviet compliance; aggressive improvements and modernization programs; and vigorous research and development programs. The two weapons programs specifically considered to be needed to satisfy the second assurance were the Trident submarine and the B-1 bomber.[5]

In the international context, the bilateral politics of arms control has seemed to several administrations to require the United States to have weapons development progams in progress to pressure the Soviets into agreement or to use as bargaining chips in negotiation. The Nixon administration's Safeguard ABM program is the most clear-cut example of a bargaining chip. Further, the desire of many national leaders in both the United States and the Soviet Union that their countries project an image of strength within the international system has encouraged them not only to increase the number but also to improve the qualitative characteristics of their nuclear forces. Indeed, for purposes of international signalling and image projection, national leaders often seem to believe that the size and composition of existing forces are less important than what new programs are underway.

ARMS CONTROL CONSIDERATIONS

Arms control considerations that argue for constraint are often overwhelmed by these others in decisions about technological change because the latter have powerful constituencies within the decisionmaking process of each country. This is particularly so when the technological change under consideration is not constrained by an existing arms control agreement. The objective of achieving an agreement for which negotiations are anticipated or even underway has rarely won out in R&D and weapons acquisition decisions over other competing objectives, including the objective of some not to achieve agreement. But even an explicit agreement that constrains innovation may not always render arms control considerations predominant over others. The Soviet Union's

[5] U.S. Congress. House, Committee on Foreign Affairs. Agreement on Limitation of Strategic Offensive Weapons. Hearings, 92d Cong., 2d sess., July 20, 27, and Aug. 2 and 9, 1972. Washington, U.S. Government Printing Office 1972. Testimony of Adm. Thomas H. Moorer, Chairman of the Joint Chiefs of Staff, p. 51, and testimony of Hon. Melvin R. Laird, Secretary of Defense, p. 45. See also Newhouse, John. Cold Dawn: The Story of SALT. New York, Holt, Rinehart and Winston, 1973, p. 246.

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construction of an early warning radar at Krasnoyarsk and the Reagan administration's reinterpretation of the ABM Treaty's constraints on the development and testing of space-based ballistic missile defense technology seem to suggest examples of this occurrence.

Arms control considerations certainly do not always argue for restraint in technological change. Innovations that improve command and control and reduce the vulnerability of nuclear forces, for example, are widely agreed to promote arms control objectives. The development of new weapons systems is sometimes considered to be a bargaining tactic that promotes agreement. Moreover, other considerations do not always promote innovation and new systems. The list of technological opportunities foregone or exploited only slowly and of nuclear weapons programs cancelled for strategic, economic, organizational or political reasons is lengthy. However, arms control considerations have often been opposed by a combination of others with the former promoting restraint and the others prompting innovation. Whether to save money, reduce incentives to initiate war, facilitate verification, or pursue some other arms control objective, arms control proponents frequently oppose technological innovation. But at least some organizational and political interests always support the pursuit to technological change and they can mobilize strategic and economic arguments to bolster their cause. Indeed, organizational and political pressures for innovation tend to mount as a new technology or weapon system proceeds through the research, development, test, production, and deployment cycle because sunk costs rise, competitive systems are abandoned, and careers, reputations, and organizational identity come increasingly to depend on the successful completion of the cycle.

IMPLICATIONS

The foregoing discussion has two implications. First, arms control considerations tend frequently to be subordinated to others in domestic decisionmaking and rarely have much influence over the rate and direction of technological change. Second, arms control agreements to constrain technological changes are very difficult to achieve when such changes are perceived to have strategic, economic, organizational, or political significance.

B. Verification Requirements

The need for each side to be able with quite high confidence to verify compliance by the other with any important nuclear arms control agreement also makes constraint on technological change difficult, although not always impossible, to achieve through arms control. This is the case because incipient technological change is frequently difficult to detect until it has evolved so far that compliance with an agreement to constrain it can no longer be verified with high confidence.

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CONCERNS ABOUT VERIFICATION

The concern about verification in the consideration of arms control agreements derives from two related sources. First, each side wants to know, with a high degree of confidence, that the other is not violating an existing agreement or could not violate a proposed one in a way that provided military advantage.[6] Second, governments need reassurance about their adversaries' good faith and compliance with arms control agreements in order to overcome mutual suspicion and distrust. Such reassurance can only be obtained through high-confidence verification of agreements. Of these two considerations, the second normally requires higher confidence in verification capability. Given the large number of nuclear weapons currently deployed, a verification capability that had, for example, a 95-percent probability of detecting an excess deployment of 20 missiles but only a 50-percent probability of detecting a five-missile excess might be judged adequate to ensure no militarily significant violation could go undetected. But if decisionmakers were highly suspicious that an opponent was disingenuous in its arms control commitments and only assurance of strict compliance could induce them to enter into agreement, the suggested level of uncertainty in the ability to detect a five-missile violation might be judged insufficient.

CONSTRAINTS ON DEPLOYMENT

Technological change can in principle be inhibited by agreement anywhere along the research, development, test, production, and deployment continuum. However, verification of an agreement not to proceed beyond a certain stage is usually most difficult for research and development and, depending on the technology, may be easiest at the test or deployment stage.

Research and early development involve laboratory work that is usually very difficult to detect by national technical means of verification (by which is meant national assets such as land-, sea-, and space-based radars, signal interception assets and observation satellites) if an opponent tries to prevent detection. Research and laboratory development have not been prohibited in any nuclear arms control agreement. Production is also a difficult stage at which to verify compliance because a determined adversary might be able to produce weapons in a manner and in locations where detection by national technical means of verification might be difficult and unreliable. For this reason, production bans have been little considered in U.S.-Soviet negotiations since the 1960's.[7] However, the

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[6] Violation might also provide political advantage, but presumably only if others were aware of the prohibited activity. Verification, therefore, would not be at issue.

[7] Proposals for a ban on the production of weapons-grade fissile material have been made recently by nuclear freeze proponents. See, for example, Forsberg, Randall. A Bilateral Nuclear Weapons Freeze. Scientific American, v. 247, November 1982, pp. 52-61; and Levi, Barbara, and Frank Von Hippel. A Cutoff in the Production of Fissile Material for Nuclear Weapons. F.A.S. Public Interest Report, v. 38, February 1985, pp. 3-7. In 1982, Soviet Foreign Minister Andrei Gromyko, in a speech to the Second Special Session on Disarmament at the United Nations, expressed Soviet interest in an agreement "to discontinue the production of fissionable material for the creation of various types of nuclear weapons." Gromyko Reviews Soviet Disarmament Stand. The Current Digest of the Soviet Press, v. 34, July 14, 1982, p. 7.

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SALT II agreement did include commitments by the Soviet Union not to produce more than 30 Backfire bombers a year and not to produce SS-16's or the missile's third stage, reentry vehicle or device for targeting the reentry vehicle.[8] The difficulty in verifying compliance with the latter provisions suggests the problems implicit in production bans.

The deployment stage is usually considered to be the easiest at which to verify numerical constraints by national technical means and was relied upon for this purpose in all SALT agreements. It is also an appropriate stage at which to consider banning innovations, such as mobile ICBM's or air-launched ballistic missiles (ALBM), that by their nature are both detectable and readily distinguishable from existing systems. If these conditions are not met by new technology, however, verification of a deployment ban is very difficult. In the cases of banning nuclear weapons deployed in space and on the seabed, agreement was reached even though detection of violation would be quite difficult; low-confidence verification was judged to be acceptable in those cases.

TESTING BANS

For most innovations, the deployment stage is often not appropriate for imposing constraint on technological change through arms control agreements. Examples include MIRV'ing and improvements in missile accuracy or nuclear explosives technology that cannot be readily detected by observing deployed systems or deployment operations and nuclear cruise missiles that cannot be readily distinguished from weapons, such as nonnuclear cruise missiles, that are not constrained. The reason is that once testing of such innovations has gone very far—some would say once testing has begun—uncertainty exists whether enough was learned to permit unverifiable deployment of systems embodying the innovation. To constrain technological change in such cases, arms control intervention at an earlier stage, particularly testing, is most appropriate. A ban on testing, especially if imposed before any testing has occurred, may provide a high degree of confidence that a new technology will not be deployed, because its performance would be too uncertain. Moreover, field testing, as opposed to laboratory testing, is usually observable by national technical means and therefore compliance with a test ban can be verified.

Prohibition on testing has been proposed in many areas as a means of constraining technological change of nuclear weaponry and has been adopted in some instances. Although a comprehensive nuclear explosives test ban has never been agreed to, testing in all environments except underground is prohibited for parties to the 1963 treaty. An unratified treaty that the United States and Soviet Union assert they are not violating prohibits underground tests larger than 150 kilotons.[9] The ABM treaty prohibits testing of

[8] Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Offensive Strategic Arms (signed June 18, 1979) (hereafter called SALT II), article IV, paragraph 8, Common Understanding.

[9] Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Tests (signed July 3, 1974), article I, paragraph 1.

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air defense systems in an ABM mode, of multiple warhead ABM's and rapid reload launchers and of sea-, air-, and space-based and mobile land-based ABM systems. The SALT II Treaty which, although unratified, both the United States and the Soviet Union have stated they will not take any action to undercut, prohibits testing of new heavy missiles, of more than one new light ICBM and of other potential technological innovations.

INADEQUACIES OF TESTING BANS

Testing prohibitions as a way of constraining technological change have their inadequacies. A complete ban on testing—of all nuclear weapons or of ICBM's, for example—to prevent innovation might result in the degradation of confidence in existing systems that otherwise is maintained by occasional tests.[10] To some, such degradation in confidence would be regarded as beneficial because, they argue, it would make initiation of nuclear war unlikely.[11] But to others, such degradation would be an intolerable weakening of deterrence, especially when the level of confidence an opponent retains in his system is unknown.

Uncertainty also exists about whether the technological innovation that a test ban is intended to inhibit could continue without tests. Certainly, the atmospheric nuclear test ban of 1963 has not significantly inhibited the evolution of nuclear explosives technology because underground testing proved quite an adequate replacement. Despite the strong engineering tradition of not believing a new technology will work until it has been tested realistically, some critics of test bans argue that an opponent could achieve significant innovation even if it conducted only undetectable, laboratory-scale testing. This argument becomes more powerful if the test ban were imposed after field testing had begun. The combination of laboratory testing and even the most preliminary field tests arguably might be enough to permit (possibly undetectable) deployment to go forward. It was an anticipation that the Soviets might not find a test ban attractive after U.S. testing began that led some advocates of a negotiated ban of MIRV's in 1968 and of antisatellite weapons in 1983 to argue for a delay in U.S. field testing pending the outcome of arms control discussions with the Soviets.[12] In the case of antisatellite weapons, the U.S. Congress legislated such a delay.[13]

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[10] For a discussion of stockpile reliability and varying views on the questions of whether a comprehensive test ban would lead to its degradation, see U.S. Congress. House. Committee on Armed Services. Intelligence and Military Application of Nuclear Energy Subcommittee. Panel on the Strategic Arms Limitation Talks and the Comprehensive Test Ban Treaty. Effects of a Comprehensive Test Ban Treaty on the United States National Security Interests. 95th Cong., 2d sess. Aug. 14, 15, 1978. Appendix 3. Washington, U.S. Government Printing Office, 1978. (Hereafter cited as House Committee on Armed Services, Panel on SALT and CTB Treaty, Effects of a Comprehensive Test Ban Treaty.)

[11] For a statement of this view applied to testing of ballistic missiles, see Turner, Stansfield. "A Note to Gorbachev." The New York Times, Oct. 22, 1985, p. A31.

[12] On the MIRV tests, see Greenwood, Making the MIRV, pp. 123–128. On antisatellite weapons, see Pike, John. Antisatellite Weapons. F.A.S. Public Interest Report, v. 36, November 1983; and Garwin, Richard L., Kurt Gottfried, and Donald L. Hafner. Antisatellite Weapons. Scientific American, v. 250, June 1984, pp. 45–55.

[13] In the fiscal year 1984 Department of Defense Authorization Act (Public Law 98–94, sec. 1235) testing of antisatellite warheads against objects in space was prohibited "unless the President determines and certifies to the Congress (1) that the United States is endeavoring, in good

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INADEQUACIES OF DEPLOYMENT AND TESTING BANS

Bans on deployment and on testing, share two other inadequacies. First, even when detection of a violation is highly likely, unequivocal interpretation of the data can be difficult. For example, the detection of seismic events is easier than discriminating between nuclear tests and natural occurrences such as earthquakes. This has been a longstanding theme in the debate over the verifiability of a comprehensive nuclear test ban. Ambiguities also exist in interpreting data from recent Soviet tests of the SS-25 to determine whether they are permitted under the terms of the SALT II agreement as contributing to the improvement of an existing type of ICBM or prohibited flight tests of a new ICBM.[14]

Second, an opponent who carries development of a new technology all the way up to the prohibited stage is building a capability to engage in prohibited activities and fosters uncertainty whether violation or renunciation of the agreement is planned. If so, the prohibited activity might be carried out more quickly than compensating action could be taken. This concern about what is called breakout is obviously more serious for deployment bans that permit de-

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faith, to negotiate with the Soviet Union a mutual and verifiable ban on antisatellite weapons; and (2) that, pending agreement on such a ban, testing of explosive or inert antisatellite warheads against objects in space by the United States is necessary to avert clear and irrevocable harm to national security." The language of the conference report (H. Rept. 98-567) for the fiscal year 1984 Department of Defense Appropriations Act (Public Law 98-212) withheld procurement funding until the President had submitted a report to Congress on "U.S. policy on arms control plans and objectives in the field of ASAT systems." Although the language of the requirement did not appear in the public law, the required report was delivered on Mar. 31, 1984 (U.S. President, 1981—(Reagan). U.S. Policy on ASAT Arms Control).

During 1984 the Congress further required in the fiscal year 1985 Department of Defense Authorization Act (Public Law 98-525), section 205) that no tests of the U.S. antisatellite system could be conducted against an object in space until 15 days after the President had determined and certified to Congress that the United States was endeavoring in good faith to negotiate "mutual and verifiable agreement with the Soviets with the strictest possible limitations on ASAT's, that pending such agreement tests against objects in space are necessary to avert clear and irrevocable harm to national security, that such testing would not constitute an irreversible step that would gravely impair prospects for negotiations, and that such testing was fully consistent with the ABM Treaty." In addition, no more than two successful tests against objects in space were allowed during fiscal year 1985. (The Continuing Appropriations Bill (Public Law 98-473) that included Department of Defense Appropriations for fiscal year 1985 increased this number to three, but deleted the word "successful.")

The required determination and certification were signed and forwarded to Congress on Aug. 20, 1985. In the FY 1986 omnibus continuing appropriations resolution (PL 99-190), Title VIII, Section 8097, Congress prohibited the expenditure of funds for testing of antisatellite weapons against an object in space until the President certifies to Congress that the Soviet Union has conducted, after October 3, 1985, a test against an object in space of a dedicated antisatellite weapon.

For a more complete discussion of congressional actions with respect to the antisatellite system, see U.S. Library of Congress. Congressional Research Service. "Star Wars": Antisatellite and Space-Based BMD. Issue Brief No. IB81123, by Marcia S. Smith, Feb. 20, 1985 Washington, 1985, pp. 15-18 and ASATs: Antisatellite Weapon System, Issue Brief No. 85176, by Alfred Manfredi, Mar. 12, 1986.

[14] SALT II, article IV, paragraph 9 permits the flight testing of only one new type of ICBM. The First Agreed Statement to this paragraph defines new type ICBM as any ICBM which is different from those ICBM's flight-tested as of May 1, 1979 in any one or more of the following respects: (a) the number of stages, the length, the largest diameter, the launch-weight, or the throw-weight of the missile; (b) the type of propellant (that is, liquid or solid) of any of its stages. The first Common Understanding to this Agreed Statement defines "different" to mean "a difference in excess of five percent." The United States has asserted that "the SS-X-25 is a prohibited second 'new' type of ICBM" (U.S. The White House. Office of the Press Secretary. The President's Unclassified Report to the Congress on Soviet Noncompliance With Arms Control Agreements (Feb. 1, 1985), p. 7). The Soviets, however, assert the SS-25 is not more than 5 percent different from the existing SS-13 in relevant characteristics. For a useful discussion of the technical issues involved with the SS-25 dispute and opinions on various sides, see Smith, R. Jeffrey. A New Soviet Missile Angers the White House. Science. Vol. 228, Apr. 12, 1985, pp. 155-157.

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velopment and testing than for test bans that permit research and development. For that reason, all the prohibitions of deployment of new technological capabilities in the SALT agreements include bans on testing and most include bans on development as well. But even banning development and testing as well as deployment does not solve the problem. Both the United States and the Soviet Union are currently concerned that research on space-based ballistic missile defense conducted by the other is providing a basis for rapid breakout of the ABM Treaty. Moreover, technology with important military applications is sometimes developed within purely civilian and therefore unconstrained R&D programs.

HUMAN INTELLIGENCE AND ONSITE INSPECTION

The foregoing discussion has presumed that verification would be conducted exclusively by national technical means, but that is not necessarily the case: Human intelligence and onsite inspection could supplement national technical means. Human intelligence about an opponent's nuclear weapons R&D or deployment programs may sometimes be available and can be very useful. However, given the closed nature of Soviet society and the degree of secrecy imposed there on all military activities, the United States cannot count on receiving useful human intelligence and what it does receive may be of doubtful or uncertain reliability.

Onsite inspection has often been proposed to supplement national technical means of verifying arms control agreements, although the Soviets have historically been quite unwilling to agree to it. The nuclear test ban negotiations since the mid-1970's have been an exception. Onsite inspection provisions were included in the unratified agreement of 1976 on peaceful nuclear explosions [15] and were to be included in the comprehensive test ban treaty partially negotiated during the Carter administration.[16] Some U.S. observers have interpreted Soviet acceptance of limited onsite inspection in these instances as an indication of their willingness to accept it in other arms control arenas. There is other evidence, too, that the Soviet Union may be becoming more open to on-site inspection. In his speech of January 15, 1986, General Secretary Gorbachev asserted a willingness to accept on-site inspection to verify his ambitious disarmament proposal.[17]

However, in the nuclear weapons arena the degree of intrusiveness of onsite inspection that would be required to verify constraints on research, development, testing, production, or deployment bans that could not be verified by national technical means is likely to go well beyond what the Soviets and even the United States would be willing to tolerate. This subject has been receiving a considerable amount of attention within the U.S. Government in

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[15] Protocol to Treaty Between the United States of America and the Union of Soviet Socialist Republics on Underground Nuclear Explosions for Peaceful Purposes (signed May 28, 1976).

[16] House Committee on Armed Services, Panel on SALT and CTB Treaty, Effects of a Comprehensive Test Ban Treaty, Statement of Rear Adm. Thomas D. Davies, p. 131; World Armaments and Disarmament, SIPRI Yearbook 1981, Chapter 11 and Appendix 11A.

[17] Nuclear Disarmament by the year 2000. Statement of Mikhail Gorbachev, General Secretary of the CPSU Central Committee, January 15, 1986. The New York Times, February 5, 1986. p. A13.

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recent years, including attempts to develop hardware that would facilitate nonintrusive onsite inspection.

CONCLUSION

The conclusion of this discussion is that the difficulty in verifying agreements that really constrain the rate or direction of technological change discourage the pursuit of such agreements. As we shall see in the next section, very few have been reached.

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III. THE HISTORICAL RECORD

The historical recored of efforts to influence technological change in nuclear weaponry through arms control agreements can be divided into four categories: Successes, failures, absences of effort, and indirect encouragement. The examination of each category suggests four conclusions. First, with few exceptions, agreements have affected technological developments relatively little. For example, they have prohibited things with little military significance to either side, or the prohibited activities, although significant, could not have been carried out over the duration of the agreement. In other instances, agreements have been ambiguous enough to permit an interpretetation that did not restrict intended innovation. Second, where an agreement to constrain technological innovation would have been meaningful at the time of the agreement, it has almost always not been sought or been sought by one side unsuccessfully. Third, in the case where an agreement was intended to constrain technology that might become significant in the future, once this significance emerged, a way was found to escape from the constraint. Fourth, arms control agreements or the efforts to achieve agreement have occasionally indirectly encouraged the adoption of technology either to serve as a bargaining chip or because it was left unconstrained by the agreement.

A. SUCCESSES

The list of areas of potential technological change that have been constrained or cut off by arms control agreements is quite lengthy. As explained in the following discussion, however, these successes have been "unimportant," designed to be of too short duration to be meaningful, or too ambiguous to be actually constraining.

UNIMPORTANT CONSTRAINTS

As unimportant constraints on technological change, one can cite four: The ban on emplacing or testing nuclear weapons in Antarctica, in the 1961 Antarctic Treaty; [1] the ban on placing nuclear weapons in orbit around the earth, on celestial bodies or in outer space in any other manner, contained in the 1967 Outer Space Treaty [2] and reaffirmed and extended to include fractional orbital missiles in SALT II; [3] the ban on emplanting or emplacing nuclear weapons or facilities for launching, storing, or testing nuclear weapons on the seabed and the ocean floor and in the ocean subsoil (except for coastal States within their 12-mile coastal seabed zone)

[1] The Antarctic Treaty (entered into force June 23, 1961), article I.

[2] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (entered into force Oct. 10, 1967), article IV.

[3] SALT II, article IX, paragraph 1(c).

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contained in the 1972 Seabed Arms Control Treaty [4] and reaffirmed in part and extended to the coastal seabed and internal and inland waters by SALT II; [5] and the SALT II ban on long-range (in excess of 600 kilometers) ballistic missiles and launchers for such missiles on surface ships.[6]

These constraints are unimportant for two reasons. First, they close off avenues of innovation which, if pursued, would not provide a military capability qualitatively different from that already possessed by both the United States and Soviet Union. Although orbital weapons and long-range ballistic missiles on surface ships could provide less warning time and attack from different directions than ICBM's, SLBM's were already deployed or being deployed that had these characteristics. Weapons in Antarctica or on, in, or under the sea floor would also not be militarily different from weapons on submarines. Second, these constraints are unimportant because the prohibited technologies or weapon systems were not regarded as cost-effective or attractive for other reasons by either country at the time agreement was reached to ban them. The Soviets had deployed 18 fractional orbital missiles. These were required by SALT II to be removed from their launchers, 12 of which were to be dismantled and 6 of which could be converted to test launchers.[7] The fact that deployed weapons were required to be removed from service is in a sense significant but, by 1979, the lack of value of fractional orbital missiles had been recognized. The only significant characteristic the other categories of weapons possessed was that once deployment would have begun, verification of numerical constraints would have been difficult.

There is one notable exception to the characterization of these constraints as unimportant. Although not anticipated at the time that the Outer Space Treaty was agreed to, the possibility of using nuclear explosions in space to pump X-ray lasers for ballistic missile defense system now looks attractive to some. The prohibition of nuclear weapons in orbit, therefore, has acquired a potential importance. As a result, however, its durability has been placed in doubt.

SHORT DURATION SUCCESSES

The agreed technological constraints that, although potentially significant, were of too short duration for their significance to be realized were contained in the unratified SALT Treaty and its protocol. The protocol was intended to be in force for only 2½ years unless extended by a follow-on agreement. It banned:

—deployment of mobile ICBM launchers and testing of ICBM's from mobile launchers,

—deployment of cruise missiles with more than 600-kilometer range on sea-based or land-based launchers;

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[4] Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Seabed and the Ocean Floor and in the Subsoil Thereof (entered into force May 18, 1972), articles I and II.

[5] SALT II, article IX, paragraph 1(b).

[6] SALT II, article IX, paragraph 1(a).

[7] SALT II, article VII, paragraph 2, Second Agreed Statement, First Common Understanding.

—flight testing cruise missiles with more than 600-kilometer range and multiple independently targetable warheads from sea-based and land-based launchers; and

—flight testing and deploying air-launched ballistic missiles.[8]

These constraints were potentially significant because they prohibited weapons with strategic value, some of which were actually of interest to one or both parties at the time of agreement. However, neither side was capable of carrying out the prohibited actions over the time period of the protocol.[9] Unless extended in subsequent agreement, therefore, these constraints would have had no practical significance. Had the SALT II Treaty been ratified and follow-on discussions occurred immediately, as had been anticipated by both governments at the time of agreement, some of these constraints might have been made more enduring by subsequent agreement and therefore become significant, but that is by no means certain. The Joint Statement of Principles and Basic Guidelines for Subsequent Negotiations that accompanied the SALT II Treaty indicated the intention that these issues be further negotiated, but did not bind the parties to an extension of the protocol's provisions.[10] In fact, the provisions of the protocol were not extended beyond its expiration date and those technologies deemed useful have been or are being tested and deployed.

The SALT II Treaty itself prohibited the development, testing, or deployment of systems for rapid reload of ICBM launchers and constrained missile and bomber modernization in significant ways:

—The development, testing, and deployment of heavy SLBM's and heavy air-launched ballistic missiles and of mobile launchers for heavy ICBM's were prohibited; [11]

—Testing and deployment of a new heavy ICBM was prohibited; [12]

—Development of a new heavy ICBM larger than existing heavy ICBM's was prohibited; [13]

—Only one new light ICBM was permitted to be tested during the period of the treaty; [14]

—This permitted new light ICBM and any new ASBM's could not be tested or deployed with more than 10 MIRV's; [15]

—Existing ICBM's could not be tested with more MIRV's than the maximum number with which they had been flight tested up to the date the treaty was signed; [16]

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[8] Protocol to the Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Strategic Offensive Arms (hereafter called SALT II Protocol), article I, article II, paragraphs 1 and 2, and article III.

[9] This point was made at the time for U.S. programs by the Chairman of the Joint Chiefs of Staff. See U.S. Congress. Senate. Committee on Armed Services. Military Implications of the Treaty on the Limitation of Strategic Offensive Arms and Protocol Thereto. Hearings, 96th Cong., 1st sess., July 24, 1979. Washington, U.S. Government Printing Office, 1979. (Hereafter cited as Senate Committee on Armed Services, Military Implications of the Treaty on the Limitation of Strategic Offensive Arms and Protocol.) Statement of Gen. David C. Jones, p. 154.

[10] Joint Statement of Principles and Basic Guidelines for Subsequent Negotiations on the Limitations of Strategic Arms, objective 3.

[11] SALT II, article IX, paragraph 1 (d), (e), and (f).

[12] SALT II, article IV, paragraph 9.

[13] SALT II, article IV, paragraph 7.

[14] SALT II, article IV, paragraph 9.

[15] SALT II, article IV, paragraphs 11 and 13.

[16] SALT II, article IV, paragraph 10.

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—SLBM's could not be tested or deployed with more than 14 MIRV's; [17]

—Existing bombers could not be equipped for more than 20 cruise missiles of range in excess of 600 kilometers and new bombers could not be fitted to carry on average more than 28 cruise missiles of range in excess of 600 kilometers; [18]

—Flight-testing from and deployment on aircraft of cruise missiles with a range in excess of 600 kilometers and capable of carrying multiple, independently targetable warheads were prohibited.[19]

Taken together, and if extended to apply beyond the 6½-year period of the SALT II Treaty, these provisions could have imposed significant constraints on the rate and direction of technological change of nuclear weaponry. But judged over the treaty's intended lifetime, the constraints were of minimal value. On the U.S. side, no technological change that was regarded as desirable or feasible within the intended period was constrained by these prohibitions. On the Soviet side, the constraints were possibly significant in two areas. The Soviets might have wanted to increase the number of MIRV's carried by their ICBM's beyond permitted numbers and probably could have done so over the relevant time period. In addition, the Soviets wanted to—and did—test two new light missiles. In the latter case, the United States has charged that the tests of the SS-25 constitute "a violation of the Soviets Union's political commitment to observe" SALT II.[20] However, the Soviets argue that the SS-25 is another version of an older missile, not a new type under the treaty's definition.[21]

AMBIGUOUS CONSTRAINTS

Of longer duration but ambiguous, were the constraints on ICBM launchers and heavy ICBM deployments included in the SALT I interim agreement and the SALT II Treaty and the prohibitions against development and testing of space-based ballistic missile defense systems, especially those resting on different physical principles than those underlying ballistic missiles defense technology extant in 1972.

The SALT I interim agreement prohibited the construction of new ICBM launchers and constrained the modernization and replacement of existing ICBM's and ICBM launchers by prohibiting the conversion of ICBM launchers for light or old heavy ICBM's into launchers for newer heavy ICBM's and by requiring that the size of launchers not be significantly increased.[22] Despite U.S. efforts to obtain Soviet agreement to a definition of "heavy ICBM," none was achieved. Moreover, the best the United States could

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[17] SALT II, article IV, paragraph 12.
[18] SALT II, article IV, paragraph 14.
[19] SALT II, article IX, paragraph 2.
[20] U.S. President, 1981- (Reagan). Arms Control Agreements. Message From the President of the United States Transmitting a Report on Soviet Noncompliance With Arms Control Agreements. Feb. 1, 1985. Department of State. Special Report No. 122, p. 5.
[21] See section II, note 14.
[22] Interim Agreement Between the United States of America and the Union of Soviet Socialist Republics on Certain Measures With Respect to the Limitation of Offensive Arms (entered into force Oct. 3, 1971, hereafter called SALT I Interim Agreement), articles I and II and agreed statement C.

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achieve as a definition of "significant increase" of silo size was what the U.S. Government asserted was a common understanding not to increase present dimensions more than 10–15 percent.[23] These ambiguities permitted the Soviets to argue that their deployment of SS–19's in SS–11 silos was permitted by the interim agreement, although some U.S. observers felt it violated the intent of the agreement.[24]

The prohibition against building new fixed ICBM launchers and the constraint on enlarging existing launchers were extended in SALT II. Moreover, the latter constraint was defined to mean no increases in volume in excess of 32 percent compared to volumes prior to SALT I [25] and the definition of heavy ICBM's was clarified to mean any ICBM larger than an SS–19.[26] However, the deployment of significantly larger ICBM's in old SS–11 launchers had already occurred. The ambiguities of SALT I prevented the agreement from inhibiting this technological change as intended.

Similar ambiguities in the definition of fixed ICBM launchers in SALT II permitted the United States to propose basing modes for the MX missile that relied upon fixed semihardened shelters, the multiple protective shelter basing mode, and new hardened silos, the so-called dense-pack basing mode, while asserting compliance with the treaty. The United States claimed that in these basing modes the launcher would not be the fixed shelter or silo but, in the first case, a launcher designed to be movable from one shelter to another and, in the second case, the canister containing the missile, placed into the silo but capable of being moved. [27] The Soviets signed the SALT II Treaty knowing that the United States planned to deploy the MX in multiple protective shelters, thereby arguably acknowledging the plan's consistency with the treaty, and supporters of the dense-pack basing mode asserted that the same principle applied to it. Both of these deployment modes have now been abandoned for the MX. The constraints or arms control agreements were not the cause in the case of multiple protective shelters, however, and were one of several causes in the case of dense-pack.

Article V of the ABM Trea'y of SALT I prohibits the development, testing and deployment of sea-based, air-based, space-based and mobile land-based ABM systems and their components. [28] The short-term importance of these constraints on technological change was not that they prohibited something that either side wanted to

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[23] SALT I Interim Agreement, Common Understanding A. This and other common understandings, however, were not actually part of the agreement.

[24] See Gray, Colin S. SALT I Aftermath: Have the Soviets Been Cheating? Air Force Magazine, Nov. 1975, pp. 32–33. The official U.S. positon on this question is that deployment of the SS–17 and SS–19 in SS–11 silos was not a violation of the interim agreement. See U.S. Department of State. Bureau of Public Affairs. Compliance With SALT I Agreements. Special Report No. 55, July 1979, p. 2. The issue is not mentioned as a violation in U.S. Department of State. Bureau of Public Affairs. Soviet Noncompliance With Arms Control Agreements. Special Report No 122, Feb. 1, 1985.

[25] SALT II, article IV, paragraph 4.

[26] SALT II, article II, paragraph 7 and paragraph 5, Third Common Understanding.

[27] See Office of Technology Assessment. MX Missile Basing, September 1981, pp. 45–50, and U.S. Library of Congress, Congressional Research Service. The Effectiveness of the Proposed Closely Spaced Basing Mode for Protecting the MX Missile: Preliminary Analysis. Report No. 82–145F, Aug. 25, 1982, pp. 36–38.

[28] Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems. (entered into force Oct. 3, 1972) (hereafter called ABM Treaty), article V. 1.

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do at the time of the agreement. However, the U.S. Navy had studied sea-based ABM systems during the 1960's; [29] by 1972 some technologies for space-based ballistic missile defense were already being researched; and multiple launchers or rapid reload launchers could clearly enhance the capability of any ABM system that was deployed, including those permitted by the treaty. The significance of article V, therefore, was that it was intended to close off technological avenues that might become attractive in the future and that, if they did, might be highly significant. Indeed this article is the best example of arms control being used for such a purpose.

Of course, research on space-based as well as new land-based technologies did continue in both countries. Already by the late 1970's, some U.S. observers, particularly in Air Force intelligence circles, had become concerned that the Soviets might be preparing to break out of the treaty and deploy an ABM system employing particle beams.[30] With President Reagan's March 23, 1983, speech, calling for a new scientific effort to find a way to defend against ICBM's, U.S. national policy changed from being officially opposed to ballistic missile defense to being in favor of it, if a technologically viable approach could be developed. The research effort, particularly on space-based technologies, was expanded and a highly visible organization was created to coordinate the effort. The Soviets have now become concerned that the United States may be preparing to break out of the treaty with a space-based ABM system.[31]

The important question has now arisen, therefore, to what extent does article V of the ABM Treaty actually constrain the evolution of space-based ballistic missile defense technology. No definitive answer is possible because asserted ambiguities of the treaty have led to conflicting interpretations in two respects. The first is the matter of exactly what is and is not allowed by the prohibition against developing and testing space-based ABM systems and their components. The second is the question of whether this prohibition applies at all to technology based on physical principles different from those on which ballistic missiles defense technology extant in 1972 was based.

The words "develop" and "test" of article V are not defined in the ABM Treaty. However, Gerard Smith, the chief U.S. negotiator, elaborated on their meaning in a prepared statement submitted to the Congress during ratification hearings. Ambassador Smith told the Congress:

> The obligation not to develop such systems, devices, or warheads would be applicable only to that state of development which follows laboratory development and testing. The prohibition on development contained in the ABM Treaty would start at that part of the development process where field testing is initiated on either a prototype or breadboard model. It was understood by both sides that the prohibition

[29] See Proposals Due on Seaborne ABM System. Aviation Week and Space Technology. July 17, 1967, pp. 43 and 45; SABMIS Future Uncertain. Aviation Week and Space Technology, Oct. 23, 1967, p. 61.

[30] See, for example, Robinson, Clarence A., Jr. Soviets Push for Beam Weapon. Aviation Week and Space Technology, May 2, 1977, pp. 16–23. For a discussion of the controversy on this subject, see Wade, Nicholas. Charged Debate Erupts over Russian Beam Weapon. Science, May 27, 1977, pp. 957–979. For a technical criticism of the notion that the Soviets could be close to succeeding in such an endeavor, see Garwin, Richard. Charged-particle Beam Weapons? The Bulletin of the Atomic Scientists, October 1978, pp. 24–27.

[31] See Soviet Embassy. Information Department. The United States Violates Its International Commitments, Jan. 30, 1984, p. 4.

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on "development" applies to activities involved after a component moves from the laboratory development and testing stage to the field testing stage, wherever performed.[32]

This explanation has spawned conflicting interpretations on the question of whether all field testing or only field testing of breadboard or prototype models is prohibited. U.S. arms control advocates and the Soviet Union support the former view.[33] Under this interpretation several elements of the Strategic Defense Initiative as now designed involve future tests that would probably be in violation of article V.

However, the Reagan administration's interpretation is more permissive. According to a Department of Defense report, field testing of space-based (as well as sea-based and mobile land-based) ABM systems, components, and their prototypes and breadboard models are prohibited by article V; all other field testing of systems and components is permitted and the development and testing of subcomponents are not constrained by the treaty.[34] The field testing program of the Strategic Defense Initiative has been constructed to avoid violating this official, permissive interpretation of the treaty's constraints and has been found by the Office of Technology Assessment to achieve this objective.[35]

This ambiguity about the meaning of article V may ultimately be less important than the question whether it applies at all to the advanced technologies being developed for space-based ballistic missile defense by both the United States and the Soviet Union. Agreed statement D to the 1972 ABM Treaty says:

> In order to insure fulfillment of the obligation not to deploy ABM systems and their components except as provided in Article III of the Treaty, the Parties agree that in the event ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are created in the future, specific limitation on such systems and their components would be subject to discussion in accordance with [review and amendment procedures] of the Treaty.[36]

Until recently, the Reagan administration's official position was that this agreed statement did not reduce the applicability of article V restrictions to ballistic missile defense technology based on "other physical principles."

The official position has now changed, however. The administration now asserts that agreed statement D nullifies the application of article V to ballistic missile technologies based on "other physical principles," meaning technologies other than ABM interceptor missiles, launchers and radars. Therefore, the space-based technology being developed in the Strategic Defense Initiative may be de-

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[32] Statement of Gerard Smith. U.S. Congress. Senate. Committee on Armed Services Military Implications of the Treaty on the Limitation of Anti-Ballistic Missile Systems and the Interim Agreement on Limitation of Strategic Offensive Arms. 92d Cong., 2d sess. Washington, U.S. Government Printing Office, 1972, p. 377.

[33] See, for example, Longstreth, Thomas K., John E. Pike and John B. Rhinelander. The Impact of U.S. and Soviet Ballistic Missile Defense Programs on the ABM Treaty. National Committee to Save the ABM Treaty, March 1985, p. 9. For the Soviet view, see Taubman, Philip. Soviet Military Chief Accuses U.S. of Distorting Terms of ABM Pact. The New York Times, Oct. 19, 1985, p. 3.

[34] Department of Defense. Report to the Congress on the Strategic Defense Initiative. 1985, Appendix B.

[35] Office of Technology Assessment. Ballistic Missile Defense Technologies. September 1985, Appendix A.

[36] ABM Treaty, Agreed Statement D.

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veloped and tested without constraint. Although for now the Strategic Defense Initiative only includes work that would be allowed if (the administration's permissive interpretation of) article V did apply,[37] this view of the ABM Treaty would greatly reduce the extent to which it constrains technological development.

Others, including the Soviet Union and Gerard Smith, disagree with this interpretation of the ABM Treaty and argue that agreed statement D in no way reduces the applicability of article V to technology based on "other physical principles." In their view, all aspects of the Strategic Defense Initiative and the Soviet Union's parallel R&D program must be governed by the prohibition against development and testing of space-based ABM systems and components.[38]

CONCLUSIONS

Having examined the historical examples of nuclear arms control agreements constraining technological change, some general conclusions can be stated. In no case has an agreement inhibited technological change that the United States both actually wanted to pursue at the time of agreement and was capable of pursuing during the intended duration of the agreement. Only in one area of technological innovation (i.e., SALT II constraints on the number of MIRV's on existing missiles) is it possible that such agreements actually inhibited Soviet programs, although in another (test on new light ICBM's) their program is claimed by the United States to violate the SALT II Treaty that the Soviets have stated they will not undercut. Agreements have been reached, with few exceptions only when they prohibited things with little military significance to either side, when prohibited activities, although significant, could not have been carried out within the duration of the agreement anyway, or when they were ambiguous enough to permit an interpretation that did not restrict intended innovation. The ABM Treaty is an important exception. There a conscious effort was made to constrain technology that, while not ripe for exploitation at the time of agreement, was seen as potentially important in the future.

This does not mean that other agreements accomplished nothing with respect to constraining technological change. Intentions and technological possibilities change and at least the long-term agreements might conceivably constrain technological changes that, although not attractive at the time of the agreement, become so later. This is not necessarily always the case, however. In the arena of ballistic missile defense, when the constrained technological opportunities came to seem attractive, the constraints gave way to reinterpretation of the treaty propelled by the force of changed strategic notions and organizational interests.

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[37] Mohr, Charles. U.S. Negotiators of ABM Treaty Say Reagan is 'Harpooning' Pact. The New York Times, Oct. 12, 1985, p. 14. Markham, James M. Shultz Assures NATO on ABM Pact. The New York Times, Oct. 16, 1985, p. A10. Mohr, Charles. 'Star Wars' Dispute. The New York Times, Oct. 17, 1985, p. A4.

[38] Taubman, Philip. Soviet Military Chief Accuses U.S. of Distorting Terms of ABM Pact. The New York Times, Oct. 19, 1985, p. 3. Smith, Gerard. How the Administration Amended the ABM Treaty. The New York Times, Oct. 23, 1985, p. A22.

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B. Failures

Four areas of technological change can be cited where efforts to impose constraint through arms control have been unsuccessful: The evolution of nuclear weapons technology; hard target kill capability; mobile ICBM's; and cruise missiles. In each case, serious attempts were made by at least one of the two superpowers to constrain the evolution of technology or to prevent deployment of new types of systems, but no agreement was reached.

NUCLEAR WEAPONS TECHNOLOGY

As already mentioned, one objective of supporters of a comprehensive nuclear test ban has always been to prevent the further evolution of nuclear explosives technology and thereby prevent deployment of new nuclear weapon systems for which existing explosive designs would be insufficient. The extent to which the evolution of explosives technology would have been arrested by a comprehensive test ban, given abilities to continue testing nonnuclear components of the explosives and to predict how the nuclear components would behave, is uncertain. Moreover, the value of arresting this evolution for constraining new weapon systems deployment has, of course, been declining with time as the number and variety of nuclear explosive designs have increased. Nonetheless, achieving a comprehensive test ban has been a stated objective of the U.S. and Soviet Governments for most of the postwar period. In the early 1960's such an agreement seemed almost within reach.[39] Serious negotiations were also undertaken in the late 1970's.[40] Nonetheless, such agreement has not been achieved.

Agreement prohibiting nuclear weapons tests in the ocean, atmosphere, and space was achieved in 1963,[41] and agreement to prohibit undergound testing above 150 kilotons was reached in 1976.[42] Although the latter and its subsequent companion treaty on peaceful nuclear explosions[43] were never ratified by the United States or the Soviet Union, both sides claim to be abiding by the testing restriction.[44] These partial restrictions on nuclear testing, however, have not arrested the evolution of nuclear explosives technology or constrained the development of nuclear weapon systems.[45]

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[39] Jacobson, Harold, and Eric Stein. Diplomats, Scientists and Politicians: The United States and the Nuclear Test Ban Negotiations. Ann Arbor, University of Michigan, 1966, pp. 38–47.

[40] For a summary of the status of these negotiations at the time of discontinuance, see World Armaments and Disarmament, SIPRI Yearbook 1981. Chapter 11 and Appendix 11A.

[41] Treaty Banning Nuclear Weapon Tests, in the Atmosphere, in Outer Space and Under Water (entered into force Oct. 10, 1963).

[42] Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Weapon Tests (signed May 28, 1976).

[43] Treaty Between the United States of America and the Union of Soviet Socialist Republics on Underground Nuclear Explosions for Peaceful Purposes (signed May 28, 1976).

[44] Each side, however, has raised concerns about the compliance of the other. The Soviets assert that "there have been repeated instances of the American side exceeding the imposed ceiling on the yield of the tested nuclear devices." (Soviet Embassy, United States Violates, p. 5.) The United States has alleged that "Soviet nuclear testing activities for a number of tests constitute a likely violation of legal obligation." (The White House, President's Unclassified Report, p. 4.

[45] A possible exception to this statement may occur in the area of nuclear pumped lasers. Although such systems have been tested underground, their evolution may now be impeded by the inability to test them more realistically in space.

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HARD TARGET KILL CAPABILITY

As a Soviet capability to destroy U.S. ICBM's in their hardened silos loomed on the horizon in the late 1960's with the testing of the large SS-9 ICBM's (first with one, then with three warheads), the United States set as a primary objective of its nuclear arms control policy constraining the further improvement of Soviet countersilo capability.[46] The U.S. architects of the SALT I interim agreement hoped that it would meet this objective by imposing limitations on large missiles and constraining the extent to which ICBM launchers could be enlarged. However, the agreement's previously mentioned ambiguities permitted Soviet ICBM programs to continue unimpeded. The generation of missiles they first tested in 1972 and 1973 had yield and accuracy characteristics and carried sufficient MIRV's to pose, at least in theoretical analyses of nuclear exchanges, a very significant threat to the U.S. ICBM force.

The United States continued to pursue the objective of contraining Soviet countersilo capability in SALT II negotiations. Some progress was made in the SALT II treaty by continuing the limitations on heavy missiles, obtaining a definition of heavy missiles, and constraining the number of MIRV's that ballistic missiles were permitted to carry. Nonetheless, the effort was largely unsuccessful. Although uncertainty about how the Soviet missile force would actually perform in a countersilo attack is large,[47] for planning purposes, the U.S. ICBM force is now widely regarded as vulnerable to a Soviet first strike.

The United States tried again during the START negotiations. The United States proposed cutting ICBM and SLBM forces to a total of 850 launchers with no more than 5,000 warheads, of which no more than 2,500 would be on ICBM's; imposing a limit of 210 on Soviet heavy ICBM's (SS-18's) and medium ICBM's (SS-17's and SS-19's), with a sublimit of 110 on heavy ICBM's; and cutting Soviet throw-weight by more than half.[48] If anything like this proposal were accepted by the Soviets, a real constraint would be imposed on their countersilo capability, although, if the number of U.S. silos was reduced simultaneously, the Soviets might still possess sufficient accurate warheads to render U.S. ICBM's vulnerable. So far, however, they have shown no interest in accepting such constraints.

The next generation of U.S. ICBM's and SLBM's will render Soviet ICBM's vulnerable in the same theoretical sense that U.S. ICBM's now are. Already highly accurate maneuvering reentry vehicles with digital correlation radar for homing on targets are being deployed on the Pershing II missiles deployed in Europe and similar technology can be employed on ICBM's and SLBM's. The efforts to employ arms control to prevent the technological changes that would make ICBM's vulnerable failed. In restrospect, only the outright banning of MIRV's would have made a significant differ-

[46] Newhouse, Cold Dawn, chapters 4 and 5.
[47] Bunn, Matthew, and Kosta Tsipis. The Uncertainties of a Preemptive Nuclear Attack. Scientific American, v. 249, November 1983, pp. 38–47.
[48] Talbott, Strobe. Deadly Gambit. New York, Knopf, 1984, p. 271.

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ence [49] but, as we shall see below, neither side was willing to accept this.

MOBILE ICBM'S

During the negotiation of the SALT I agreements, the United States sought Soviet acceptance of a ban on mobile ICBM's. The special concern about mobile missiles was that, once deployment had begun, counting the number deployed would be very difficult. The issue was given special urgency because the Soviets were already testing the SS–16, a mobile ICBM. The Soviets would not agree to such a ban, however, and the United States eventually withdrew its insistence that it be included. However, the United States declared unilaterally that it "would consider the deployment of operational land-mobile ICBM launchers during the period of the Interim Agreement as inconsistent with the objectives on that Agreement."[50] Whether because of the seriousness with which the Soviets knew the United States regarded the matter or because of technical problems they were said to have with the SS–16, the Soviets did not deploy the missile.[51] Nonetheless, the attempt by the United States to ban mobile missiles by agreement in SALT I can be regarded as an effort that failed.

The issue of SS–16's was addressed again during the SALT II negotiations. The SALT II Treaty explicitly banned the production, test, and deployment of the SS–16 and of its third stage, its reentry vehicle, and its device for targeting. The purpose now, however, was to prevent the transformation of SS–20's, theater-range ballistic missiles made up of two of the three stages of the SS–16's, into SS–16's.[52] By the mid-1970's, the United States was considering deploying its own new ICBM, the MX, in a mobile basing mode to prevent its being vulnerable to Soviet attack. The Soviets also continued to be interested in pursuing a mobile basing mode for its fifth generation ICBM's. Mobile missiles were not banned by the SALT II Treaty, therefore, although deployment was precluded for 2½ years by the protocol.

Whether, on balance, the absence of an agreed ban on mobile ICBM's is to be regretted or applauded is a matter of some ambiguity. Unless carefully designed to permit the other side to count the number of missiles deployed, as the Carter administration's multiple protective shelter system was to have been, deployment of mobile missiles would render verification of a future arms control agreement difficult. However, by increasing the portion of the nuclear forces that could survive a counterforce first strike, mobile ICBM's would reduce the current anxiety about the presumed incentive to initiate such an attack. Today mobile ICBM's are widely perceived in the United States to promote arms control objectives or at least not be inconsistent with them. Nonetheless, the Novem-

[49] Yield-accuracy combinations still could result in vulnerability of hardened ICBM's, but the exchange ratio would almost certainly favor the party attacked if the attacker did not have MIRV's.

[50] SALT I Interim Agreement, Unilateral Statement B, Land Mobile ICBM.

[51] Department of State, Compliance With SALT I, p. 6.

[52] SALT II, article IV, paragraph 8 and associated Common Understanding. The United States asserts that the Soviet Union has probably violated this provision of SALT II. The White House, President's Unclassified Report, p. 7.

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ber 1985 arms control proposal of the Reagan administration included a ban on mobile missiles.[53]

CRUISE MISSILES

During the negotiation of SALT II, the Soviet Union tried unsuccessfully to constrain U.S. deployment of long-range cruise missiles. Indeed, this effort and the U.S. desire to include Soviet Backfire bombers within the constraints on heavy bombers were the main causes of the lengthy delay in completing the SALT II Treaty after the overall framework was agreed to at Vladivostok in 1974. The SALT II protocol's prohibition of deploying cruise missiles of a range in excess of 600 kilometers on sea-based or land-based launchers [54] only prohibited what the United States would not be able to do within the 2½-year duration of the constraint. Deployment of the U.S. air-launched cruise missile, not constrained by the treaty, and of land-based, sumbarine-launched and surface ship-launched cruise missiles went ahead as scheduled. The Soviet Union has done similarly.

C. Absence of Effort

The gradual evolution of technology that permits incremental improvement to existing types of nuclear weaponry has not been significantly influenced by arms control, primarily because one or both sides did not want it to be. All three SALT ageements explicitly permit modernization (the replacement of existing systems with new, more capable ones of the same type) within their modestly constraining guidelines. Four technological areas where no real effort has been made to influence the rate and direction of innovation through arms control are particularly noteworthy because they have been or potentially are of great strategic significance. These are MIRV'ing, accuracy improvement, silo hardness, and antisubmarine warfare (ASW).

MIRV'ING

Testing of the first MIRV'ed missiles—the Minuteman III ICBM and Poseidon SLBM—began in 1968, the year before the SALT negotiations began. Despite considerable interest in Congress and the country in the possibility of banning MIRV's in order to avoid the threat to fixed ICBM's that later developed, neither party to the negotiation made a serious effect to reach such an agreement.[55] The United States proposed a test and deployment ban, the latter to be verified by onsite inspection, a proposal it knew that the Soviet Union would not accept because it was opposed to all onsite inspection. The Soviets countered with a proposal for a deployment ban that would let testing continue, to be verified by national technical means. They knew this would be unacceptable to the United States because of the difficulty of verifying a deployment ban without onsite inspection, once testing has been conducted. Neither side

[53] Boyd, Gerald M. Reagan Proposes U.S.-Soviet Accord on Mobile Missiles. The New York Times, Nov. 2, 1985, p. 1.
[54] SALT II Protocol, article II, paragraph 1.
[55] Newhouse, Cold Dawn, pp. 179–181; Greenwood, Making the MIRV, pp. 130–135.

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proposed the obvious middle ground of a test and deployment ban without onsite inspection. This option was widely discussed in the United States, and the intelligence community was divided on whether it could be adequately verified.[56] It may be that the United States did not propose it because of the uncertainties in verification and that the Soviet Union did not propose it because of a reluctance to freeze a technology that the United States had tested but it had not. More likely, however, neither side proposed this approach because both preferred proceeding with MIRV technology over constraining it. It provided a cost-effective way of increasing the number and effectiveness of offensive warheads for use against the full range of targets. Both sides' offensive strategic modernization programs were dominated by MIRV'ed missiles.

SILO HARDNESS AND ACCURACY IMPROVEMENT

The objectives of reducing incentives to initiate war and of being able to destroy an opponent's warmaking capability to enhance deterrence or limit damage are in conflict when considering the technologies of silo hardness and accuracy improvement. Improving hardness of one's own fixed ICBM's and command and control centers makes them more survivable and thereby renders an opponent's first strike less effective. But constraining an opponent's ability to improve hardness would enhance one's own counterforce capability. Similarly, constraining an opponent's accuracy improvements would reduce his ability to destroy one's own ICBM's, thus reducing his incentive to initiate war, but letting one's own accuracy improve without constraint would improve one's ability to destroy the opponent's warmaking capability.

The historical record shows no sign that either side has tried to encourage or constrain the evolution of these technologies through arms control. Encouragement was certainly not needed because the technologies continued to evolve almost as quickly as human ingenuity and the opportunities for fielding new advances permitted. Constraints may not have been sought because both sides perceived their interests would be served by continual evolution of the technologies. But at least the United States might have perceived an interest in constraining silo hardness improvements in the period since the mid-1970's when the Soviets were observed upgrading their silos to a hardness believed to exceed that of U.S. silos. Moreover, during the negotiation of SALT II, the concern about emerging Soviet hard target kill capability might have tipped the United States in favor of accuracy constraints, had they been feasible. But silo hardness and accuracy improvement technology share the characteristic that constraints on technological improvement could not be verified with high confidence by national technical means. That alone would have prevented serious consideration of either one as a candidate for negotiated constraint, even if appropriate incentives did exist.

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[56] Greenwood, Making the MIRV, p. 130.

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ANTISUBMARINE WARFARE

Antisubmarine warfare constraints have also not been sought through arms control negotiations, although attention has been given the subject in the U.S. policy literature.[57] The reasons are several. First, both sides have probably believed that in the competition between improving the technology to detect, acquire for targeting, and destroy submarines and enhancing the survivability of submarines by making them quieter and letting them operate in a larger ocean area, the latter would win out. There would be no need, therefore, to constrain ASW in order to ensure the survivability of the SLBM force. Second, ASW directed against ballistic missile submarines and ASW directed against attack submarines overlap almost completely. At least for the United States, the latter capability is so important to the nation's ability to fight a large-scale conventional war that constraining the technology would be considered unacceptable. Third, a signficant asymmetry has always existed in the two countries' ASW capabilities. The United States would presumably be unwilling to accept constraints in this area where it has been and expects to stay significantly ahead. The Soviets would probably be unwilling to freeze themselves into a position of permanent inferiority.

D. Indirect Encouragement

Arms control negotiations and agreements seem to have encouraged technological change indirectly in several areas. These include cold-launch techniques for ICBM's, ABM, and cruise missiles.

COLD-LAUNCH TECHNIQUES

The prohibition on constructing new fixed ICBM launchers and the constraints on increasing the size of existing ICBM launchers in the SALT I interim agreement might have induced or speeded up the development and deployment of cold-launch techniques for ICBM's. Cold-launch means that the missile is ejected from its silo prior to engine ignition. This may facilitate reusing the silo quickly to launch another missile and permits the deployment of a signifcantly larger missile in a silo than would be possible using the older techniques of having the missile engines ignite inside the silo. With the latter, used for Minuteman III and older Soviet missiles, rocket exhaust badly damages the silo and would damage the missile if an air space were not left around it in the silo. The Soviets began testing cold-launch technology shortly after the SALT I agreements were signed and began deploying cold-launched missiles, specifically the SS-17 and SS-18, within 3 years.

SAFEGUARD ABM

Whether the Nixon administration regarded its Safeguard ABM system from the time it was proposed exclusively as a bargaining chip to induce Soviet agreement to offensive constraints is uncer-

[57] Garwin, Richard L. Antisubmarine Warfare and National Security. Scientific American, v. 227, July 1972, pp. 14-25; and Tsipis, Kosta, Anne H. Cahn, and Bernard T. Feld. The Future of the Sea-Based Deterrent. Cambridge, Mass., MIT Press, 1973.

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tain but seems unlikely. By 1972, however, in light of the system's many technical weaknesses that had been identified, and with strong opposition to it in the Congress and the country, its role as a bargaining chip was probably the primary reason that Congress continued funding it. The ABM deployment at Grand Forks Air Force Base, therefore, almost certainly occurred because of the system's alleged value in the context of arms control bargaining with the Soviets. In 1975 the Congress voted to shut it down.

CRUISE MISSILES

Observers of the decisionmaking process involved with the U.S. cruise missile programs have argued that arms control considerations were an important factor in determining the pace and orientation of these programs.[58] The constraints on ballistic missiles built into SALT I and later anticipated for SALT II encouraged attention to cruise missiles as an unconstrained avenue of technological change. Moreover, a vigorous cruise missile program was seen as a way both of compensating for the disparities favoring the Soviet Union that the military and many Members of Congress saw in the SALT I agreement and of keeping pressure on the Soviets to agree to what would be seen in the United States as a more equitable SALT II agreement.

[58] Art, Robert J., and Stephen E. Ochenden. The Domestic Politics of Cruise Missile Deployments. In Betts, Richard K., ed. Cruise Missiles: Technology, Strategy and Politics. Washington, Brookings, 1981. Chapter 12.

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IV. THE EFFECTS OF TECHNOLOGICAL ASYMMETRIES ON ARMS CONTROL

The fact or prospect of technological change in any area relevant to nuclear weaponry influences arms control in a manner that is *sui generis*, sometimes encouraging control of itself or in other areas and sometimes inhibiting agreement. Nonetheless, most of the ways in which these effects occur can best be understood not by examining each area separately, but by focusing on the phenomenon of technological asymmetry.[1] The existence of asymmetry is one of the most striking conclusions of any comparison of U.S. and Soviet nuclear capabilities, either current or past. Asymmetries exist, of course, with respect to the size and composition of the nuclear forces of the United States and Soviet Union and these have had profound effects on nuclear arms control. However, these lie beyond the scope of this paper. Of concern here are the asymmetries that exist with respect to the state of technology relevant to nuclear weaponry.

The technological asymmetries derive in part from the different levels of overall technological capabilities in the two countries and in part from policy choices made in each capital with respect to the amount and direction of R&D investment. To cite some examples, U.S. missile guidance technology has historically been better than Soviet, U.S. submarines have been quieter, and the United States deployed MIRV's and modern long-range cruise missiles first. But Soviet silos are believed to have been harder in recent years, the Soviets deployed a significant antisatellite system before the United States, and the size and number of Soviet missiles combined with the MIRVing and accuracy improvements of the current generation and taking into account silo hardness, have given the Soviets a better hard target kill capability than the United States has currently.[2] The Soviets were the first to begin deploying an ABM system, but U.S. technology in this area has tended to be better than Soviet. Such technological asymmetries can act either as promoters of arms control agreements or as inhibitors, depending on the context. We shall examine each possibility in turn.

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[1] One important effect of technological change that does not show up with this approach is the extent to which the evolution of verification technologies has facilitated agreements. This subject is addressed explicitly in another paper in this series.

[2] By the latter point is meant that the Soviet Union is able to destroy on a first strike a larger fraction of U.S. silos than the United States on a first strike could destroy of Soviet silos. However, as Warner Schilling has pointed out, under these conditions the United States can destroy a larger fraction of Soviet warheads than the Soviet Union can destroy of U.S. warheads. Schilling, Warner. U.S. Strategic Nuclear Concepts in the 1970s. International Security, v. 6, No. 2, Fall 1981, p. 72.

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A. Asymmetry as a Promoter of Agreement

A technological asymmetry can be a promoter of arms control agreement both for the technological leader and for the technological follower. In the former case, a technological lead can sometimes provide bargaining leverage and at other times encourage a willingness to accept negotiated constraints in other areas. In the latter case, a technological lag can provide an incentive to reach an agreement that constrains the technological evolution of the leader.

BARGAINING LEVERAGE

A technological lead can provide bargaining leverage at any stage in the evolution of technology from research to deployment. But this occurs only if the likelihood of deployment is perceived by one's opponent to be high in the absence of agreed constraints and if the country possessing the lead is willing to bargain away the possibility of exploiting it. The Safeguard ABM system fit this bill for the United States quite well in the early 1970's. The Nixon administration was willing to relinquish its right to deploy almost all of the system in exchange for Soviet agreement to limit offensive systems. However, despite the strong domestic opposition, the administration repeatedly succeeded in convincing Congress to continue funding at least a scaled down version. The Soviets clearly were concerned about the possibility of a large-scale U.S. ABM deployment and were impressed with the level of U.S. technology. Their interest in arresting the U.S. program apparently acted as a significant incentive for them to agree to offensive limitations.[3] MIRV, on the other hand, was not a U.S. bargaining chip during SALT I nor were cruise missiles during SALT II, because the United States was not willing under any plausible circumstances to give them up.[4]

COMPENSATION

MIRV technology prior to 1972 and cruise missiles prior to 1979 did, however, promote arms control in a different way: They compensated the United States for certain numerical advantages allowed the Soviet Union in the agreements. During the domestic debates over ratification of SALT I and SALT II agreements, administration officials pointed to the U.S. leads in both areas, left intact by the agreements, as reasons why the agreements were not contrary to U.S. interests. In particular, MIRV and the advantage in warhead numbers MIRV technology provided were said to compensate for the Soviet numerical advantages in ICBM's and SLBM's and in ICBM throw-weight that SALT I did not eliminate.[5] Cruise

[3] See the discussion of the linkage between offense and defense in the SALT I negotiations in Newhouse, Cold Dawn, Chapter 5.

[4] On MIRV in Salt I, see Greenwood, Making the MIRV, pp. 130–135. On cruise missiles in SALT II, see Talbott, Deadly Gambits. Reportedly, some U.S. Government officials hoped to use cruise missiles as bargaining chips in START negotiations, but lost out in interagency discussions to those who were intent on preserving this area of U.S. advantage. See, Talbott, Deadly Gambits, pp. 241–242.

[5] See U.S. Congress. House. Committee on Foreign Affairs. Agreement on Limitation of Strategic Offensive Weapons. Statement of Admiral Moorer, p. 49; U.S. Congress. Senate. Committee

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missiles were claimed to compensate for Soviet throw-weight advantages and the Backfire bomber that was regarded by some as a heavy bomber but was not counted in the SALT II limits.[6] These examples show that possession of a technological lead can sometimes induce a party to an arms control negotiation to accept less than it would ideally like from an agreement.

CONSTRAINING THE LEADER

Being technologically behind can also act as an incentive for obtaining arms control agreements. The objective would be to constrain the opponent or prevent the exploitation of his lead. In part, this is the obverse of the bargaining chip argument. If the bargaining chip works for the technological leader, it does so by giving the follower an incentive to reach agreement. As mentioned, being behind in ABM technology in the early 1970's did give the Soviets an incentive to reach agreement in offensive weapons and thereby obtain U.S. agreement to arrest Safeguard deployment. Throughout the 1970's, the United States also perceived an incentive to try to constrain the Soviet antisatellite capability. Under President Carter three rounds of negotiations with the Soviets were held on this subject but no agreement was reached before the United States terminated discussions following the Soviet invasion of Afghanistan.[7] In the absence of success and with the United States developing a much more capable antisatellite system than the Soviets have, they now have an incentive to seek arms control constraints on U.S. capability. They have acted on this incentive by requesting that the United States cease its testing and by stressing their long-standing interest in negotiating an agreement on space weapons.[8]

B. Asymmetry as an Inhibitor of Agreement

Technological asymmetry can also inhibit arms control agreement, again from the point of view of both the leader and the follower. The technological leader may want to exploit his lead and therefore be unwilling to accept an agreement that constrains the evolution of the technology or prohibits embodying it in deployed weapons. This is perhaps particularly true for the United States which has traditionally viewed technological prowess as one of its most important assets in its military and political competition with the Soviet Union. A country that is behind in some important technological arena might also be reluctant to reach agreement constraining technological innovation if it would thereby be frozen into permanent technological inferiority.

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on Armed Services. Military Implications of the Treaty on the Limitation of Anti-Ballistic Missile Systems and the Interim Agreement on Limitations of Strategic Offensive Arms. 92d Cong., 2d sess., June and July 1972. Washington, U.S. Government Printing Office, 1972. Testimony of Secretary of Defense Melvin Laird, p. 149.

[6] See U.S. Congress. Senate. Committee on Armed Services. Military Implications of the Treaty on the Limitation of Strategic Offensive Arms and Protocol Thereto (SALT II Treaty). Testimony of Gen. David C. Jones, p. 154.

[7] U.S. Library of Congress. Congressional Research Service. "Star Wars": Anti-Satellite and Space-Based BMD. Issue Brief No. IB81123, by Marcia Smith, Feb. 20, 1985 Washington, 1985.

[8] See, for example, Gromyko TV "Conversation" With Political Observers. FBIS Daily Report: Soviet Union, Jan. 14, 1985, pp. AA1–AA16.

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PREFERENCE FOR EXPLOITATION

Several examples can be cited of both the United States and the Soviet Union being unwilling to reach agreement that would have prevented exploitation of a technological lead. For the United States, being unwilling to consider seriously a ban on MIRV's during SALT I negotiations and significant constraints on cruise missiles during the negotiation of SALT II are prime cases. Also the U.S. unwillingness to include a prohibition of mobile missiles in SALT II, except in the protocol, derived from a desire to deploy the MX missile as a mobile ICBM in a multiple protective shelter mode. On the Soviet side, the unwillingness to agree to a definition of a heavy missile in the SALT I interim agreement almost certainly resulted from an intention to deploy its improved, fourth generation ICBM, the SS-19, which is significantly larger than the SS-11.

UNWILLINGNESS TO FREEZE INFERIORITY

Being behind in technology also can inhibit arms control agreement. Although, as already mentioned, an incentive may exist for the lagging country to reach an agreement that constrains further evolution or exploitation of the leader's technological advantage, sometimes the cost of making a position of inferiority permanent is unacceptable. During negotiations on a nuclear test ban in the late 1950's and early 1960's, for example, influential U.S. opponents argued that the Soviet test program had included designs and revealed knowledge relevant to ballistic missile defense not yet available to the United States and that agreeing to a test ban would leave the United States at an important and unacceptable disadvantage.[9]

Similarly, the Soviets' apparent unwillingness to propose serious consideration of a MIRV ban during SALT I negotiations may have resulted from an unwillingness to perpetuate a situation where the United States had tested MIRV and could break out of an agreed ban and deploy relatively quickly but the Soviets had not yet tested a real MIRV. In addition, the Soviets might have believed that, despite a short-term disadvantage, the larger throw-weight of their ICBM's, their silo hardening programs, and their ability to exploit MIRV technology without facing the kind of domestic opposition that the MX missile has faced in the United States, would make them better off in the long run with MIRV permitted on both sides. In retrospect, many U.S. observers would agree that unrestricted MIRV'ing has served Soviet advantage more than U.S. and for that reason fractionation limits—preventing an increase in the number of MIRV's permissible beyond the status quo—were sought and included in the SALT II Treaty.

The U.S. reluctance in recent years to seek a ban on antisatellite systems could derive in part from an unwillingess to accept an asymmetry where the Soviet Union has a deployed system—even though that system is not very good—but the United States has not. Of course other considerations are also relevant. Opponents of

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[9] U.S. Congress. Senate. Committee on Foreign Relations. Nuclear Test Ban Treaty. 88th Cong., 1st Cong., 1st sess., Aug. 20, 1963. Washington, U.S. Government Printing Office, 1963. Statement of Edward Teller, pp. 417–427.

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a negotiated ban on antisatellite weapons perceive a serious problem of verification, even if the Soviets agree to dismantle their existing system, and anticipate that in the long run the United States can establish and maintain an edge in the technologies of destroying others' satellites and protecting one's own.

C. The Influence of Asymmetry

As we have seen, technological asymmetry sometimes promotes and sometimes inhibits reaching arms control agreements, and under various conditions being both ahead and behind can provide incentives in either direction. What then can be said in a general way about the influence of technological asymmetry on the ability to reach arms control agreement? Reaching conclusions is always difficult and highly uncertain, particularly when each area of technology and the circumstances of each case are so different. However, the experience we have briefly reviewed in this section does suggest some preliminary conclusions.

Technological leads seem to promote arms control in the role of bargaining chips only if the possessor of the lead believes the area of technology is sufficiently unpromising or of such little strategic value that it can be forgone with little loss, but the opponent believes or fears otherwise. If the follower believes that the technology is of little strategic value, that country will not be induced to trade anything significant to impose constraints on the leader. If the leader believes the lead can be usefully exploited, he will be very reluctant to give it up, but he may be more willing to accept an agreement that is painful in other respects if exploitation of the technological lead is not inhibited.

Technological lags can provide incentives to reach agreement if the follower believes the technology is important and either that he will not catch up technologically or that equal exploitation will favor the other side. Technological lags will provide disincentives, however, if the follower believes both that it can catch up and that unconstrained exploitation will eventually favor itself.

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V. TECHNOLOGICAL CHANGE AND THE FUTURE OF ARMS CONTROL

From the perspective of 1986 one can identify four areas of nuclear weaponry where significant technological change is being introduced or on the horizon that either will influence arms control negotiations now underway or are candidates for encouragement or limitation through arms control agreement. These are long-range cruise missiles, ballistic missile defense, antisatellite weaponry, and some aspects of ICBM technology.[1] In this section, we shall explore each of these areas in turn. The findings in each case are different.

FINDINGS

Long-range sea-launched cruise missiles seem very difficult to constrain meaningfully through arms control agreements because of difficulties of verification. As a result they are likely to complicate and might render impossible agreement to control other categories of offensive nuclear weapons. The same is likely to become true of ground-launched cruise missiles once the Soviet version is deployed.

The continuing evolution of ballistic missile defense technology cannot be arrested totally, even if that were judged desirable, and the mutual fear of breakout from the ABM Treaty cannot be totally eliminated. The potential value of space-based ballistic missile defense technology and its likely implications for offensive arms control are hotly debated issues. What seems clear is that, in the near term, the only attainable agreement that goes beyond the existing ABM Treaty would be to expand the definition of development and testing to prohibit all field testing of space-based ABM systems, components, and conceivably subcomponents.

Disagreements also exist over whether antisatellite technology should be left unconstrained or limited by agreement. Aside from desirability, however, the feasibility of agreement is highly uncertain for three reasons: (1) The political pressures generated by current asymmetries in deployed capability and in technology; (2) the technical difficulties of verification; and (3) the difficulty of effectively constraining antisatellite technology while permitting the continuation of activities and the evolution of technologies with other purposes but possessing some intrinsic antisatellite capability.

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[1] ASW is omitted because, although there is interest in remote detection by radar or blue-green lasers, the general view still is that, given what can be done to make submarines more difficult to find, cost-effective strategic ASW is not foreseeable. If such technologies become attractive, they will doubtless be pursued. The result is likely to be changes in SSBN technology and deployment tactics to negate their effects, not attempts to constrain ASW through arms control. Either way, therefore, ASW technology does not seem to hold significant implications for arms control.

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The technology of high-accuracy, maneuvering reentry vehicles might possibly be limited through an agreed testing ban, although the technology might already be too far advanced for this to be feasible. Mobile ICBM's are being deployed by the Soviet Union [2] and might be deployed by the United States unless prohibited by mutual agreement. However, the light, mobile single-warhead ICBM currently being discussed in the United States seems quite unattractive economically and strategically unless it were deployed in the context of a Soviet-U.S. agreement that causes a significant reduction in the number of Soviet warheads.

A. Long-Range Cruise Missiles

The technology of long-range cruise missiles poses a formidable challenge to arms control in two respects. First, given how far each side has already progressed with this technology, the prospect of preventing by mutual agreement the widespread deployment of cruise missiles appears dim. Second, the difficulties involved in verifying numerical constraints on certain types of cruise missiles raises questions about whether agreement can be reached to limit other types of nuclear weaponry.

Both sides have now deployed air-launched and sea-launched versions of modern long-range nuclear cruise missiles and the United States has begun to deploy a ground-launched version in Europe and a nonnuclear version at sea. A Soviet ground-launched nuclear cruise missile is expected to be deployed soon. The Soviets are also reported to have large sea- and ground-based cruise missiles under development. Turning the clock back and banning all long-range cruise missiles or those launched from a particular type of platform now seems highly unlikely. It appears that the support for such systems within the defense communities of both countries is too strong and the difficulties of verification are too great. Numerical constraints on air-launched cruise missiles would be feasible, as they were under SALT II, but sea-launched and ground-launched versions pose very difficult verification problems.

VERIFICATION

Current versions of nuclear cruise missiles are small and can be launched from a variety of platforms. Therefore, once deployment has begun, verifying compliance with any agreed numerical limitation, including zero, by counting the number that a potentially uncooperative opponent has manufactured or deployed would be very difficult. The fact that nuclear and conventional versions of the same missile are being deployed makes the problem even worse, unless the latter were banned or constrained with the former.

The SALT II Treaty dealt with this verification problem for air-launched cruise missiles by limiting the number that could be put on each heavy bomber, constraining the number of heavy bombers allowed to carry them, and requiring that cruise missile carriers have observable differences in structure compared to non-cruise-missile carriers. This could work because neither side was interested in deploying conventionally armed long-range cruise missiles on

[2] U.S. Department of Defense. Soviet Military Power 1986, p. 26.

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heavy bombers and because aircraft are intrinsically limited in how many cruise missiles they can carry and must be specially designed to carry them.

However, both nuclear and large numbers of conventional long-range cruise missiles are now being deployed on attack submarines and surface ships. Not only do those vessels known to be platforms for cruise missiles have a large potential carrying capacity, but also virtually any ship or submarine now must be considered a potential carrier of cruise missiles. GLCM's deployed as the U.S. version is now being deployed can be counted readily. However, once the Soviet Union begins deploying its small GLCM, verifying that none have been deployed in a manner that does not permit observation would be very difficult. Virtually any large truck could be a nuclear cruise missile carrier. Moreover, the deployment of long-range conventional ground-launched cruise missiles in Western Europe has been proposed to enhance NATO's ability to attack Warsaw Pact ground forces behind the first echelon. If this were to occur and the Soviets did likewise, the verification problem for GLCM's would become even more difficult.

For these reasons, numerical limits for sea-launched cruise missiles are already not likely to be verifiable with high confidence and in the future the same might become true for ground-launched cruise missiles. The inevitable conclusion is that numerical limitations on sea-launched cruise missiles and, unless such limitations are imposed before the Soviet deployments begin, on ground-launched cruise missiles are quite unlikely to be achievable through arms control agreements unless the conventional-armed versions are also banned and the problem of possible clandestine deployment is solved. These conditions are unlikely to be met.

The experience with MIRV suggests caution in reaching such a conclusion about cruise missiles. MIRV's were widely thought for several years to preclude numerical limits on strategic missiles but eventually acceptable counting rules were developed to deal with them. A comparable solution might turn out to be possible for ground- and sea-launched cruise missiles but, if so, it is not currently in sight.

CONSTRAINING THE TECHNOLOGY

Constraining the further evolution of cruise missile technology in a number of directions might nonetheless be feasible, although not especially significant. One way would be to continue the SALT II prohibition against cruise missiles carrying multiple warheads. Such a ban would be of little value, however, unless numerical limits were also imposed because the cost advantage of putting more than one warhead on these relatively low-cost delivery vehicles is small. Moreover, verification of such a provision should be regarded as uncertain.

Another constraint of somewhat greater interest might be banning supersonic cruise missiles. The slowness of subsonic cruise missiles not only invites deployment of defenses but also means that, despite their possible high accuracy, they are not attractive weapons for a counterforce first strike if launched far from their targets. Increasing cruise missile speed to supersonic ranges, which

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is technologically feasible, would reduce the warning time and make them more useful for attacking time-urgent targets. This is especially true for sea-launched cruise missiles that might be launched within 1,500 to 2,000 miles of some missile silos. Prohibiting such improvement in missile speed would prevent cruise missiles from being included in the equation of a possible counterforce first strike. It might also be verifiable, if imposed prior to the initial testing of such systems. Its significance would be limited, however, by the existence of large numbers of ICBM and SLBM warheads that are usable for prompt counterforce attacks.

BROADER QUESTIONS

The more important issue for arms control raised by cruise-missile technology is whether, if no numerical limitations are feasible for some types, the limitation of other offensive weapons is precluded as a result. There is a precedent for the possibility of omitting certain categories of cruise missiles and achieving agreement on other types of weaponry. This is the omission of bombers from the SALT I limits. However, that agreement was reached at a time when neither side had new bombers in production and, even with the B–1 expected to become operational in the late 1970's or early 1980's, the need to retire some of the older B–52's suggested that the total number of U.S. bombers was unlikely to rise. The situation with cruise missiles is quite different today. Both sides have several types of long-range cruise missiles in active production and could, if they chose to, produce and deploy many thousands over the next few years. Omitting such a capability from arms control constraints, even if supersonic and multiple warhead cruise missiles were banned, would be extremely difficult for either side to accept. Yet because of the previously mentioned verification problems, omission of at least sea-launched and perhaps ground-launched cruise missiles seems necessary if any offensive arms control is to be achieved.

The advent of long-range cruise missiles, therefore, seems to be a technological change that is unlikely to be constrained by arms control agreements in important ways, that could enormously complicate control of other offensive arms, and might make such control much less valuable or preclude it altogether.

B. Ballistic Missile Defense

Since 1972, when the ABM treaty was signed, the technology for ballistic missile defense has evolved in several important ways. This evolution has led to a dramatic change in U.S. policy with respect to strategic defense that has stimulated vigorous debate. It has also spawned new concerns related to the ABM Treaty and the U.S. reinterpretation of the treaty's provisions constraining technological development.

TECHNOLOGICAL DEVELOPMENTS

The Soviet Union has developed and is deploying new, phased-array early warning radars (widely believed in the United Stated to include the radar being built near Krasnoyarsk, in violation of

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the ABM Treaty), new engagement management radars associated with its Moscow system, and new exoatmospheric and high-acceleration endoatmospheric ABM interceptors. A rapidly deployable ABM system is also said to be under development. The Soviets have deployed one surface-to-air missile system, the SA-10, and are flight testing another, the SA-X-12, that some U.S. observers believe have limited ballistic missile defense capability. The combination of these developments has led to concern that the Soviets might be creating a capability that could allow them to break out of the ABM Treaty and deploy a nationwide defense system within 10 years of deciding to do so.[3]

The United States has been developing highly capable interceptors for high-altitude, nonnuclear and for low-altitude, nuclear and nonnuclear destruction of ballistic missile reentry vehicles.[4] The former would be useful for either hard site or population defense. The latter, the low-altitude defense system (LoADS), would be appropriate for defense of hardened ICBM silos.

In addition, development has proceeded apace in both countries of space-based or partially space-based directed energy technology (lasers and particle beams), kinetic energy weapons, necessary target acquisition, tracking and pointing techniques, and battle management approaches that could be employed for destroying ballistic missiles shortly after launch in their boost phase before they release MIRV's and penetration aids.[5] Such technologies seem highly promising to some observers, but not to others.

Under the 1972 ABM Treaty and its 1974 protocol the current Soviet modernization of its Moscow ABM system is explicitly permitted. The U.S. deployment of LoADS or a layered defense at Grand Forks Air Force Base would be permitted also, but this has not been proposed by the U.S. Government. Soviet deployment of more than 100 interceptors around Moscow or giving ballistic missile defense capabilities to antiaircraft missiles, interceptors and radars is prohibited. Under the original U.S. and the current Soviet interpretation of the treaty, the development and testing of space-based ballistic missile defense technology is also constrained.[6] Nonetheless, the R&D and modernization activities have caused concern about possible violations of the ABM Treaty and about the potential for breakout from it. As a result, all these activities were included within the framework of negotiation for the nuclear arms control talks currently underway in Geneva.

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[3] U.S. Department of Defense. Soviet Military Power, 1985. Washington, U.S. Government Printing Office, 1985, pp. 46-48.

[4] See Robinson, Clarence A., Jr. Layered Defense System Pushed to Protect ICBMs. Aviation Week and Space Technology, Feb. 9, 1981, pp. 83-86; Robinson, Clarence A., Jr. Army Testing Hit-to-Kill, Radar-Guided Interceptor. Aviation Week and Space Technology, July 9, 1984, pp. 38-40; Robinson, Clarence A. BMD Homing Interceptor Destroys Reentry Vehicle. Aviation Week and Space Technology, June 18, 1984, pp. 19-20.

[5] See Fletcher, James C. The Technologies for Ballistic Missile Defense. Issues in Science and Technology, Fall 1984, pp. 15-29; Bethe, Hans A., Richard L. Garwin, Kurt Gottfried, and Henry W. Kendall. Space-Based Ballistic Missile Defense. Scientific American, v. 251, No. 4, October 1984, pp. 39-49; Carter, Ashton, Directed Energy Missile Defense in Space. Office of Technology Assessment, April 1984. Department of Defense. Report to the Congress on the Strategic Defense Initiative, 1985.

[6] See the discussion in the text above following note 32, section III

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TREATY VIOLATIONS

Both sides have accused the other of violating the ABM Treaty by providing a base for an ABM defense of its territory.[7] The United States has asserted that the Soviet Union has violated the treaty by building the Krasnoyarsk radar and may be violating it by building air defense missiles with ABM capabilities.[8] Clarification and resolution of these issues are likely to be on the U.S. agenda for the talks. The Soviet Union is known to believe that some elements of the U.S. Strategic Defense Initiative will violate the treaty and have made the issue of space weaponry a primary item on thier arms control agenda.

BREAKOUT CONCERNS

U.S. concern about possible breakout derives from deployment of the Krasnoyarsk and other new types of radars, from continuing Soviet R&D on and deployment of new ABM interceptors and possibly dual-use air-defense systems, and from Soviet research on space-based ballistic missile defense. On the Soviet side, similar concerns derive from the U.S. Strategic Defense Initiative. Testing and, in the Soviet case, deployment of improved ABM interceptors and radars has gone too far to prevent the current round of technological change unless a treaty amendment disallowed the 100-interceptor systems now permitted. The Soviets are unlikely to accept that. Banning laboratory research on any type of ballistic missile defense technology would almost certainly be ruled out on verification grounds alone, even if it were judged desirable. Banning the development and testing of new conventional land-base ballistic missile defense systems without also prohibiting deployments would be tantamount to prohibiting modernization. This would be a dramatic departure from historical precedent and is unlikely to be acceptable. There appears to be no way, therefore, of eliminating totally the concerns about breakout. However, banning all out-of-laboratory testing of space-based ballistic missile defense technology, even that now considered research by the United States and therefore permitted under the treaty, would reduce the concern somewhat for technologies of this type not yet tested.

BOOST PHASE TECHNOLOGIES

Research on boost-phase ballistic missile defense technologies had been underway in both the United States and Soviet Union for many years prior to President Reagan's speech of March 23, 1983. What has stimulated anew the vigorous debate on ballistic missile defense is not so much the technologies themselves, which are still in the early stages, but the President's reversal of a decade-old policy by endorsing strategic defense of the country as a highly desirable objective. He has committed the prestige of his office and has proposed committing substantial increased resources through

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[7] U.S. Department of State. Bureau of Public Affairs. Soviet Non-Compliance With Arms Control Agreements. Special Report No. 122, p. 6; Soviet Embassy. Information Department. The United States Violates its International Commitments.

[8] U.S. Department of State. Bureau of Public Affairs. Soviet Non-Compliance With Arms Control Agreements. Special Report No. 122, p. 5.

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the Strategic Defense Initiative to research and development of boost-phase technologies.

The question raised by these technologies for arms control in the near term is: Should they be viewed as bargaining chips, as pernicious threats to a valuable treaty, or as potentially leading to a highly desirable innovation? There is great disagreement in the country on the answer to this question.

PROPONENTS' VIEWS

The administration and many others believe not only that these technologies look promising from a technological perspective, but also that, if they turn out to be feasible, deployment would be highly desirable.[9] Their long-term goal is a capability that can protect the whole country and our allies from ballistic missile attack. They assert that, accompanied by capable aircraft and cruise missle defenses, a capable ballistic missile defense would permit abandoning the nuclear era's reliance on deterrence by punishment and returning to the prenuclear notion of deterrence by denial. In the short term, they seek a capability that would greatly reduce the utility to the Soviet Union of a counterforce attack and thereby eliminate the presumed threat of a disarming first strike. These defensive capabilities, they argue, would help to stabilize the strategic nuclear balance and encourage bilateral agreement to reduce drastically offensive nuclear forces. If the appraisal of the devotees of these technologies and their views of the strategic implications of success are correct, then the possiblility of this technological change must be viewed as highly conducive to offensive arms control.

The ABM Treaty would have to be abandoned, not only to deploy but (unless the administration's current interpretation of the treaty is sustained) also to test prototypes of the new technologies. But the administration and its supporters on this question clearly believe that the security and offensive arms control benefits would more than compensate. In their view the Strategic Defense Initiative should not be used as a bargaining chip in arms control negotiations, but should be viewed as a highly desirable technological and strategic revolution and pursued to its expected successful conclusion.

CRITICS' VIEWS

Critics of the President's program argue the opposite case. The technologies are not promising, they say, and any that do turn out to work will be very expensive, easily countered by a determined adversary like the Soviet Union, and quite unattractive from the perspective of offense-defense cost-exchange ratio.[10] Moreover, the

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[9] For statements of the administration's views on this issue see, The President's Strategic Defense Initiative. The White House, January 1985; Keyworth, George A. II. The Case for Strategic Defense: An Option for a World Disarmed. Issues in Science and Technology, Fall 1984, pp. 30-44; Meinel, Carolyn. Fighting MAD. Technology Review, April 1984, p. 31; and Brezinski, Zbnigniew, Robert Jastrow, and Max M. Kampelman. Defense in Space is Not "Star Wars." The New York Times Magazine, Jan. 27, 1985, p. 28.

[10] For critics views, see Drell, Sidney D., and Wolfgang K.H. Panofsky. The Case Against Strategic Defense: Technological and Strategic Realities. Issues in Science and Technology, Fall 1984,

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critics claim that any technological asymmetry in this area will increase, not decrease anxiety about a disarming first strike, either by the technological leader while he has a unique capability to neutralize his opponent's surviving forces, or preemptively by the follower before the leader acquires that unique capability. In addition, it is argued, to the extent that either the Soviet Union or the United States believes that the other can deploy a capable ballistic missile defense system, it will feel compelled to respond with new offensive weapons deployment in order to overwhelm or circumvent the system.

Pursuit of space-based defense will not facilitate offensive arms control, therefore, in this view, but render it impossible at anything like current levels of forces. In addition, the necessary abandonment of the ABM Treaty would be a serious blow to arms control and our national security. The Strategic Defense Initiative and the corresponding Soviet program are therefore seen as pernicious threats to arms control that should be constrained to the extent possible.

SDI AS A BARGAINING CHIP

Some observers have argued that the U.S. program should be used as a bargaining chip in arms control negotiations with the Soviets. Although there has been some dispute in recent years about which country is ahead in missile defense, both sides seem convinced that with Presidential interest in the subject and the launching of the Strategic Defensive Initiative, the United States should be considered the leader. That means that the United States might conceivably use its program as a bargaining chip to extract concessions from the Soviets in other areas, most probably offensive weapons.

Even if this were viewed as desirable—and the administration has adopted the view that it is not—there is still a serious question about how useful a bargaining chip the current U.S. program might be. The problem is that there is little more that could not be given up beyond what is already prohibited by the ABM Treaty. Agreeing not to do laboratory research seems infeasible because of the difficulties of verification. The existing treaty could be reaffirmed. But only an accompanying, unlikely reversal of the current U.S. endorsement of strategic defense might engender such a reaffirmation with such high political value to the Soviets that holding out the prospect could be a useful tactic for the United States. Even then, such a reaffirmation may be of little practical value because research would still continue and the treaty could still be abandoned any time in the future to permit prototype testing if that appeared desirable.

The most likely possibility for the United States using the Strategic Defense Initiative as a bargaining chip seems to be to offer to

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pp. 45–65; Tucker, Jonathan B. The Fallacy of Laser Defense: Technology Review, April 1984, p. 30; and Union of Concerned Scientists. Space-Based Missile Defense. Cambridge, Massachusetts, UCS. 1984; Drell, Sidney D., Philip J. Farley, and David Hollaway. The Reagan Strategic Defense Initiative: A Technical. Political, and Arms Control Assessment. Stanford University, July 1984; Longstreth, Thomas K., John E. Pike and John B. Rhinelander. The Impact of U.S. and Soviet Ballistic Missile Defense Programs on the ABM Treaty. National Campaign to Save the ABM Treaty, March 1985.

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return to the previous view that article V constraints apply to space-based technology based on "other physical principles," to broaden the definition of "development and testing" to prohibit all testing outside the laboratory of such technology, not just breadboard or prototype testing, and possibly to include subcomponents in the ban as well as components. Although this constraint, too, could be abandoned in the future, it would prevent technological development from proceeding as far as it could otherwise, unless a major political decision were made to abandon the treaty. Although one can only speculate about how much leverage the United States could actually obtain in negotiations by offering this change of definition, the apparently high Soviet interest in constraining the evolution of U.S. boost-phase ballistic missile defense technology [11] suggests perhaps considerable.

C. Antisatellite Weapons

Asymmetry has been the norm in the development of antisatellite weapons, with respect to both deployed capability and technology. All parties to the antisatellite debate in the United States appear to agree that an agreement prohibiting attacks on satellites, but permitting the deployment of antisatellite systems would be of little value. Such an agreement would not avoid the crisis instability that some observers argue might result if militarily valuable satellites became highly vulnerable. It could not be counted upon to hold in time of war, they argue, and would apply no break to the offense-defense competition in space. Therefore, although so-called rules-of-the-road agreements are sometimes considered on their own, the primary debate is whether a ban of deployment and testing is desirable and feasible.[12] No consensus exists on these questions in the United States, although the Reagan administration is highly doubtful. The Soviet Union, on the other hand, seems to be interested in constraining the further evolution of antisatellite technology.[13]

TECHNOLOGY AND CAPABILITY

The United States began work on antisatellite technology in the 1950's, with the Air Force SAINT Program and deployed two systems beginning in 1964, one on Kwajalein Atoll and the other on Johnston Island.[14] The former relied on the Army's Nike-Zeus ABM interceptor, the latter on the Air Force's Thor missile. Both counted on high-altitude nuclear detonations to destroy satellites that passed near their bases. Because of their limited utility and the disruption that the electromagnetic pulse from a high-altitude nuclear explosion would cause, these systems were abandoned, the Army's in 1967, and the Air Force's in 1976.

In 1968 the Soviet Union began testing a more versatile, ground-launched system and had conducted some 20 tests of three different

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[11] See, for example, Gromyko TV "Conversation" with Political Observers.

[12] For a detailed analysis of several possible antisatellite agreements, see U.S. Congress. Office of Technology Assessment. Anti-Satellite Weapons, Countermeasures, and Arms Control, September 1985

[13] Gromyko TV "Conversation" with Political Observers.

[14] For a review of antisatellite technology and systems, see John Pike, Anti-Satellite Weapons.

versions by June 1982. It has not tested since and in August 1983 declared a unilateral moratorium on further tests as long as the United States exercised similar constraint.[15] The Soviet system functions by launching a satellite, maneuvering it near the target satellite and then exploding it. The fragments destroy the target. Although the Soviet system can attack satellites in a wider range of orbits than the early U.S. systems could, it still is limited to low-earth orbits (up to 5,000 kilometers, depending on the orbital inclination) and by its nature provides considerable warning time of an imminent attack. Moreover, the failure rate of the test program does not suggest a high reliability for the system.

After years of debate and preliminary work, the United States initiated full-scale development of a new antisatellite weapon in 1977. The weapon, launched from specially fitted F-15 interceptors, uses a two-stage rocket booster to accelerate a miniature homing vehicle and carry it into the path of the target satellite. The minature homing vehicle then is self-propelled, under active guidance by an infrared seeker. Using small, on-board rockets for terminal course correction, it collides with and destroys its target. If it functions as expected—and, despite early problems, the success of the test conducted on September 13, 1985, against a target in space [16] suggests that it will—this U.S. antisatellite system will be much more capable than the current Soviet one. While still limited to near-earth orbit, it can attack satellites with essentially any inclination by flying the F-15's from appropriate bases and using airborne refueling as needed. There is little doubt that, while the Soviet Union is the leader with respect to deployed capability, the United States is now the leader in technology in this area. There is, however, no reason why the Soviet Union could not over time develop and deploy a much more capable system than it now has.

DESIRABILITY OF ANTISATELLITE ARMS CONTROL [17]

U.S. proponents of an antisatellite capability have argued that the United States should have the ability to attack high value Soviet satellites, particularly those for ocean surveillance, photoreconnaissance, and electronic surveillance.[18] While acknowledging a possible military value of such a capability, proponents of antisatellite arms control have argued that on balance the United States would be better off forgoing this capability, to forestall an improved Soviet system that would effectively threaten U.S. intelligence, navigation, weather, and perhaps ultimately communications satellites.[19]

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[15] Burns, John F. Andropov Issues a Promise on Antisatellite Weapons. The New York Times, Aug. 19, 1985, p. A3.

[16] Keller, Bill. Air Force Missiles Strikes Satellite in First U.S. Test. The New York Times, Aug. 19, 1985, p. A3.

[17] A useful summary of views and issues related to antisatellite systems and the prospects for agreed limitations on antisatellite systems may be found in, U.S. Congress. Office of Technology Assessment. Arms Control in Space. Washington, Office of Technology Assessment, 1984.

[18] See Gray, Colin S. Why an ASAT Treaty Is a Bad Idea. Aerospace America, April 1985, pp. 70-74.

[19] Garwin, Gottfried, and Hafner, Antisatellite Weapons; Pike, Anti-Satellite Weapons; Tsipis, Kosta, and Eric Raiten. Antisatellite Weapons: The Present Danger. Technology Review, August/September 1984, pp. 54-63; Hafner, Donald L. Averting a Brodingnagian Skeet Shoot. International Security, v. 5, No. 3, Winter 1980/81, pp. 41-60

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Antisatellite proponents sometimes counter that a U.S. antisatellite capability is necessary to deter Soviet use of theirs and that in a space arms competition, the United States would maintain an edge because it could both field more capable antisatellite systems and equip its satellites with better protective measures. To arms control proponents the latter argument sounds unrealistically optimistic. They assert that in this area, as in others where the United States has started with a technological lead, the Soviets will eventually catch up and the result will be an expensive offense-defense competition, a decline in confidence in valuable satellite assets, or both. They assert that it is better to accept a modest Soviet lead that does not pose a serious threat to U.S. satellites and that could be effectively and verifiably dismantled under an antisatellite ban than to invite the real vulnerability of U.S. satellites in the future by pressing an illusive and inevitably fleeting advantage.

FEASIBILITY

Aside from the desirability of pursuing a negotiated constraint in antisatellite weapons, there are serious questions about its feasibility from both a political and technical perspective. Politically the questions are whether the Soviet Union would be willing to forgo its current advantage in deployed capability and whether the United States would be willing to forgo its technological advantage. The United States is unlikely to accept constraints on its own program unless the existing Soviet capability is dismantled. An agreement could permit deployment of first generation systems on both sides. However, the Soviet Union would first have to conclude that it would rather accept the disadvantage of having an inferior system than permit both sides to pursue the technology, with all its implications for ballistic missile defense, without constraint. The most likely agreement would both prohibit the test and deployment of new antisatellite systems and require the dismantling of existing systems. This will only become politically feasible when both sides agree that, in the long term, unrestrained exploitation of the technology will not be to their advantage and that the technical problems of such an agreement can be resolved.

From a technical perspective there are two issues related to feasibility: technological commonality and verification. Many technologies can be used for antisatellite weapons, including land-based high-powered lasers, offensive ballistic missiles, ABM interceptors like the Soviet Galosh or U.S. homing overlay, direct-ascent vehicles like the U.S. system being developed, space-based directed energy systems like those being studied for ballistic missile defense in both countries and coorbital systems either unmanned like the system the Soviets have deployed or manned like the present U.S. and perhaps a future Soviet space shuttle. Many of these technologies, of course, have or could have other uses, including nonmilitary space applications and ballistic missile defense. Any antisatellite agreement that bans the deployment or testing of antisatellite weaponry must be written to permit the deployment of offensive missiles, the evolution of technologies relevant to nonmilitary purposes and, unless the ABM Treaty is to be expanded, the deployment of ABM missiles and development of other types of ballistic

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missile defense technology. This poses a difficult challenge. It might be met by framing an agreement to ban antisatellite activities, regardless of the hardware involved, rather than trying to ban particular types of hardware.[20] One might question, however, whether such an agreement has actually accomplished anything since all the technology needed for conducting antisatellite attacks might be testable in the course of carrying out allowed activities.

The extent to which various types of antisatellite bans might be verified have been very controversial and is complicated by the wide variety of technologies and systems that have or could be given some antisatellite capability.[21] The extent of Soviet tests and their existing capability introduce further significant complications. The Reagan administration is highly dubious that the dismantling of the Soviet antisatellite capability could be verified with high confidence and worries about the potential for breakout.

One reason is the small size of the Soviet antisatellite satellite and its ability to be placed on a multipurpose booster, making verification of an agreement to destroy the existing system difficult. Others are the small number of U.S. satellites that the Soviets might wish to attack, making any uncertainties in compliance significant, and the variety of systems that might be capable of the antisatellite mission.[22] Others assert that verification of dismantling could be high confidence and argue that the risk of error is low because of the limited capability and reliability of the current Soviet system. Proponents of antisatellite bans do acknowledge that some residual capability would remain in other types of systems, but argue that the real concern is dedicated systems and a ban on deployment and testing of these could be verified.[23] For new technologies, like the U.S. antisatellite system, a deployment ban would be verifiable by the United States only if accompanied by a test ban and perhaps only if the latter were imposed before testing proceeded very far.

D. ICBM Technology

Two areas of new ICBM technology are particularly important and might influence or be influenced by nuclear arms control. These are maneuvering reentry vehicles and mobile ICBM's. One version of a maneuvering reentry vehicle has already been deployed on the long-range theater ballistic missile, Pershing II, and others are likely to be placed on ICBM's (and SLBM's) in the future, unless prohibited by agreement. A mobile ICBM is now being deployed by the Soviets and may be deployed by the United States, unless prohibited by arms control agreement. If deployment of mobile ICBM's goes forward, reaching agreement on offensive nuclear weapons will be rendered much more difficult and perhaps even be precluded unless such systems are designed so that the inability of an opponent to target the missiles does not prevent verification of the number deployed. The small, single-warhead, mobile

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[20] This proposal was made by Hafner, Averting a Brodingnagian Skeet Shoot, pp. 54–55.
[21] See Office of Technology Assessment, Arms Control in Space, pp. 39–45.
[22] The President. Report to the Congress on U.S. Policy on ASAT Arms Control. Mar. 31, 1984, pp. 4–5.
[23] See Pike, Anti-Satellite Weapons, pp. 13–15.

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ICBM currently under study in the United States seems economically and strategically unattractive unless explicitly encouraged by a favorable arms control environment.

MANEUVERING REENTRY VEHICLES

Both the Soviet Union and United States have reached a range of missile accuracy where significant further improvement using standard techniques will likely come only at great cost, if at all. Such improvement is possible, however, by building homing terminal guidance and maneuver capability to ballistic missile reentry vehicles. Certainly there would be a weight penalty for such a capability, perhaps requiring smaller yield warheads or fewer MIRVs on each missile or more capable missiles. But the trade-off might well be worth making, if the result is a substantial improvement in accuracy.

Such technology is in many ways a natural evolution of both guidance and reentry vehicle technology and seems likely to be developed and deployed unless explicitly forbidden by arms control agreements. Pershing II already is employing a version of such technologies. Moreover, any agreement designed to limit warhead numbers, such as the one proposed by the United States at START, is likely to encourage this type of technological change, that would increase the value of each allowed warhead. The result would be to erode even further the ability of fixed targets to survive a nuclear attack.

Agreement to ban maneuvering reentry vehicles would be a dramatic departure from past arms control practice, which has not tried to interfere with the evolution of accuracy and reentry vehicle technology. But it is not totally out of the question. Verification might be feasible using the techniques for observing missile tests that both sides have employed for years. However, the degree of advancement already achieved with this technology and the possibility of testing at short range, totally within each country's continental land mass, will make verification difficult. Absence of constraint here is unlikely, however, to influence greatly the prospects of arms control in other areas, except to the extent that further improvements in missile accuracy exert more pressure to deploy mobile ICBM's.

MOBILE ICBM'S

Missile accuracy improvements already achieved and under way have rendered fixed, land-based ICBM's increasingly vulnerable to a counterforce first strike, despite improvements in silo hardness on both sides. Interest in mobile ICBM's, therefore, has revived. The Soviets have begun deploying the SS–25 in a road-mobile mode and the SS–X–24 is expected to be deployed in a rail-mobile mode soon.[24] Mobile ICBM's no longer appear to be stoppable through arms control agreements, therefore.

Whether the United States will move in the same direction is much more uncertain. Several mobile basing modes for MX were considered and abandoned, although the argument for deploying

[24] U.S., Department of Defense 1986 (op. cit.), p. 27.

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the missile in a mobile mode always was and still is powerful. A new small mobile ICBM is currently under study by the U.S. Air Force and has many proponents.[25] The problems of finding a socially acceptable means of deploying MX in a mobile mode do not foster optimism for this system, although some of the issues raised in that case can be avoided here as a result of the smaller size and lighter weight of the missile and its transporter.

Testing of such a missile would be prohibited as long as the SALT II constraint against testing more than one new missile is respected. Moreover, if deployment by either side of a mobile ICBM is to be consistent with the current or any likely future arms control regime, it would have to be designed so that the inability of the other side to locate and target the missiles would not also prevent verification of the number deployed. Otherwise, like cruise missile deployments, the deployment of mobile ICBM's would seriously complicate and might even preclude agreement to limit offensive nuclear weaponry.

The U.S. small ICBM is currently envisioned to carry only one warhead, but that is not necessarily the best trade-off between cost-effectiveness and the desire to avoid an offense-defense exchange ratio favorable to the offense. A mobile ICBM, especially one deployed in a transporter-erector-launcher capable of off-road movement and hardened to survive tens of pounds per square inch overpressure, would be a very expensive platform for delivering a single warhead. Moreover, unless such missiles were free to roam over vast areas of the country (not a highly likely possibility), they would be vulnerable to barrage attacks.[26] The system would therefore appear to be unattractive both economically and strategically unless it were deployed in the context of an arms control agreement that forced sharp reduction in Soviet warheads. Deployment of a larger mobile missile able to carry two or three warheads per missile, even though it might be less mobile, would probably be more cost effective and, unless Soviet counterforce capability is significantly curtailed, seems to some observers to be a preferred approach for the United States.[27] Irrespective of how many warheads a U.S. mobile ICBM might carry, however, political opposition to its deployment can be expected from citizens within the states selected to be its hosts, as well as from others. These various problems with the small U.S. ICBM have perhaps contributed to the decision to renew the U.S. proposal that all mobile ICBM's be banned by agreement.

E. Conclusions

As we have seen, the historical record of nuclear arms control contains few examples of successfully constraining significant technological change. Verification problems have been severe, and per-

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[25] For a useful discussion of the technology and the issues it raises, see U.S. Library of Congress. Congressional Research Service. Small Single-Warhead Intercontinental Ballistic Missiles: Hardware, Issues, and Policy Choices. Prepared by Jonathan Medalia. Washington, 1983.

[26] For estimates of the numbers of warheads of various yields the Soviet Union would require to destroy mobile ICBM's as a function of warning time, system operating area, and hardness, see Kaufmann, William W. The 1986 Defense Budget. Washington, Brookings, 1985, p. 17.

[27] For other implications of arms control agreements on mobile ICBM's that are essentially numerical, see Kaufmann, The 1986 Defense Budget, pp. 58–61.

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ceived strategic, economic, organizational or political advantages of exploiting new technology (often enhanced by the existence of asymmetries between the United States and Soviet Union) have tended to overwhelm arguments for restraint. There is little reason, *a priori*, to expect greater accomplishment in this area in the future, and the brief survey of four areas of evolving technology has yielded nothing to alter this expectation.

Verification uncertainties alone might be enough to preclude agreement on technological constraints in several areas. Verification might be too uncertain for a ban on antisatellite systems now that the Soviet Union has a system deployed and the United States has tested its more capable version, for a ban on sea-launched cruise missiles now that both nuclear and conventional versions are deployed, for a ban on ground-launched cruise missiles now that U.S. deployment has begun or at least once Soviet deployment begins, for a ban on maneuvering reentry vehicles now that one is deployed on the Pershing II, and for any constraints on laboratory research on space-based ballistic missile defense technology. Verification might be sufficiently high confidence to permit a ban on all out-of-laboratory testing of space-based ballistic missile defense technology if both sides wanted to impose one, but that would be controversial.

At least as important as verification uncertainties, however, is the apparent lack of agreement between the United States and the Soviet Union that constraining technological change is desirable. The Soviet Union seems eager to constrain antisatellite, ballistic missile defense and some types of cruise missile technologies, but the United States appears unwilling to do so. The United States has now declared its interest in constraining mobile ICBM technology but, given its investment in this area and its lack of domestic political opposition to deployment, the Soviet Union seems unlikely to agree.

Therefore, unless (1) the incentives each side sees for future innovation are altered and (2) the uncertainties about verification are resolved or judged acceptable, there is little prospect for agreement that imposes significant constraint on technological change. In several areas, moreover, especially cruise missiles, mobile ICBM's, and ballistic missile defense, the prospect of technological change will importantly complicate the negotiations and might preclude agreement in other areas. In the latter case, the prospect of technological change might unravel an agreement now in effect.

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